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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

APRIL, 1931

THE FUTURE OF MAN IN THE LIGHT OF HIS PAST:[1]

THE VIEW-POINT OF AN ARCHEOLOGIST

By Dr. A. V. KIDDER

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THE archeologist is a hard man to get out of the trenches, by Christmas, or at any other season. He finds so much of interest underground, and he is so comfortable and so quiet in his contemplation of the past that he hates to emerge to be dazzled and confused by the glare and hurry of the present. And as to the future, if he can look forward to a continuing supply of ruins to excavate, he is supremely indifferent.

That, of course, is just the trouble with archeology. When forced to justify his existence the archeologist solemnly states that one can not understand the present without a comprehension of the past. Granted. But he is peevishly resentful if it be suggested that he can not interpret the past save in the light of the present. A paleontologist, it might be remarked, who had never seen a cow or a dog would be puzzled to reconstruct from the fragmentary and disarticulated bones with which he must work the appearance of a primitive mammal. And so it is very good for a digger to be brought out of the ground, to be forced to face the meaning of his finds; to take stock and to determine what, if any, bearing his labors may have upon the present and the future of mankind.

When I was asked to take part in this symposium I felt that for the honor of my profession I must above all things be scientific. I should naturally have liked to assemble some statistics and to have topped them off with one of those splendid formulas that have Greek letters in them. But I've never been able properly to understand the intricacies of the statistical method, besides which no archeologist can ever bear to contemplate the magnitude of his probable error. But I thought that a graph would be the next most scientific thing I could do. So I made one—on coordinate paper—with abscissae and everything—millennia since the Old Stone Age one way, degrees of human progress the other. And I plotted on it the course of civilization. As I had also recently been reading a book on sociology I thought I ought to have a spot-map. So I made one—on Mercator's projection—a little spot for a humble culture, a big spot for a brilliant one, labeled the spots with the names of the races con-

[1] Symposium before the American Society of Naturalists, Cleveland, Ohio, January 1, 1931.

cerned and drew lines between them to mark the peregrinations of civilization.

But when they were all done I found it hard to contemplate them with equanimity, for while, according to my graph, there is a comforting general rise in the line of civilization, its upward course is interrupted by drops proportionate in violence to the speed and height of each preceding peak; and my spot-map indicated that when once a people has lost its position at the top of the heap it can not hope for future preeminence. In other words, my researches might seem to show that our present order is due for a terrific smash and that the next rise will be carried on by a race other than ours.

Of course it is pleasant to feel that there will be another rise and that civilization itself is not necessarily doomed; and perhaps the people who are going to be the next overlords will run the world more intelligently than we do. Nevertheless it is disquieting to consider even the temporary break-up of our culture or the passing of our race. What can we do about it? How can we smooth the curve, how eliminate the perhaps not inevitable drop, how keep ourselves in the cultural running?

What has happened in the past? It is of course the business of the archeologists and the historians to find out. But they have not done so. At least not convincingly. And we do not yet know why former civilizations have withered, nor do we know why their seeds, finding lodgment in new racial soil, have almost invariably produced stronger cultural offspring. A thousand explanations have been offered. The geneticist attributes slumps to bad genes and recoveries to happy combinations of good ones; the nutritionist sees things in terms of vitamins; the epidemiologist in terms of disease; the sociologist perceives faults or virtues in this or that aspect of social organization. And if all else fail, one can always join Ellsworth Huntington in feeling for the climatic pulse.

But it is obvious that no single cause can reasonably be held responsible either for the rise or for the fall of so infinitely complex a thing as a civilization. Civilization seems to grow in response to some unknown but potent force which impels all animate creatures toward better living—in other words, toward more perfect adaptation to their physical and social environments. After a half-century of research we can not honestly be more precise than that. In regard to the fall of civilizations we are in scarcely better case, but we can perhaps so phrase the matter as to pave the way for clearer understanding and open lines for renewed attack by saying that civilizations have fallen because of the failure of man to develop a *savoir vivre*, a knowing how to live, proportionate to his material achievement. If, from Paleolithic times to the present, man had been able first clearly to formulate and then successfully to solve the social, economic and physiological problems forced upon him by his growing culture, he would not have made the mistakes, genetic, sanitary, nutritional, political, military which, singly and in various combinations, have led to the retrogressions that have interrupted the steady ascent of civilization. The human race, it would seem, has always built the machinery of living faster than it has learned to run it. Which is merely another way of saying that it is fundamentally easier to make than it is to think.

And while we are thinking more and perhaps even thinking more clearly than we have in the past, we appear to be following exactly the same path as our forebears. We are failing, just as they did, to develop a social sagacity comparable to our material advance.

In many ways it would appear that

we are even more badly out of balance at the present time than we have ever been before. This, it goes without saying, is due to the unprecedented speed and scope of physical and biological discovery. On the physical side, to cite but one or two instances, the development of labor saving machinery which brought about serious social and economic difficulties a hundred years ago, appears to be inducing a second not dissimilar crisis to-day. Machine-fostered mass production, whose minutely divided jobs destroy all pride of craftsmanship, reduce workers to automatons and produce states of mind which the industrial psychologists tell us are to the last degree unhealthy. Modern transportation and communication have practically abolished space, bringing the peoples of the world into such close juxtaposition that racial tensions are being set up and racial mixtures are going on whose consequences are, to say the least, precarious. The biological sciences together with biochemistry are permitting medicine to reduce infant mortality to an unprecedented degree and thus allowing to grow to procreative maturity countless thousands of weaklings who would not otherwise have survived. And so one might indefinitely go on.

I, and the many more able thinkers who have dealt with this subject, have, as is the habit of Cassandras, stressed its darkest aspects. We are prone to forget that in the make-up of our Frankenstein there is a vast deal that is beneficent. But nevertheless his I.Q. is still lamentably low, and if he turns and rends us it will be because his material strength is not tempered by social judgment. The physical sciences have built him a noble and a terrific body, the humanistic disciplines have not yet supplied him with a brain.

It is thus the failure of students of man, rather than the success of research workers in physics and chemistry and biology, which has brought us to the pass which the graph-making archeologist views with alarm. It would be utterly impossible, even were it desirable, to stay the progress of exact science with its inevitable practical applications. If for no other reason because upon prior findings in physics, chemistry and biology must be based all real advances in humanistic understanding. Our task is therefore to bring the disciplines which concern themselves largely or in part with the less tangible aspects of human existence to parity with their brethern of the test-tube and the breeding-pen.

How can this be done? I'm not sure. The problem has puzzled much better brains than mine. But I do believe that the first and most important step is clearly to visualize and frankly to face the colossal task which confronts us. I think it is necessary for anthropologists and historians and psychologists and sociologists to realize that their problems are as much harder than those of biology, as biological problems are than those of physics. Only by grasping the fact that the inherent intricacy of their subject has made it impossible for them to keep pace with the first rush of nineteenth and twentieth century scientific achievement with its precise and satisfying findings can they be saved from the fatal inferiority complex which has really been at the bottom of so much of their flabby thinking. Furthermore, it is necessary for them fully to comprehend the difficulty of their task if they are to plan a well-advised attack upon it.

The attack has two aspects, the material and the intellectual. On the material side we must have more men and much greater funds for the support of their investigations. In this the material sciences have greatly improved our prospects, for their achievements

have shown so clearly the immense practical advantages of research that the layman is willing, as never before, to provide money for its advancement.

Granted that it may ultimately be possible to apply to the problems of man the energies of well paid and adequately financed workers, there still remains the vastly more important matter of fostering such intellectual attitudes as will permit development of a sound methodology for coping with the intricacies of human life.

In such a statement as this, one is naturally limited to generalities. One can not discuss the interrelation of the various social disciplines. As a matter of fact, one of our main troubles is that they are not interrelated nearly as closely as eventually they must be if we are to get forward. We work too much in compartments, both in subject matter and in our arbitrary divisions of historic time. Man must be considered in all his endlessly complex relationships with his fellows and at all periods of his existence. To accomplish this it is necessary to bring all students of man into close intellectual relationship. But even if this could be done, the social sciences would only be found competent to deal with those aspects of human life which are in essence extraorganic. Man, however, is also an organism and his existence is largely conditioned by biologic laws. Hence no real progress in the understanding of history, in comprehension of the present or in envisagement of the future can be made without knowledge of the action of such laws. Some method must therefore be worked out for free intercourse between biologists and humanists. For the latter it is absolutely essential. I also believe that it would be of value to biologists, particularly to those who give thought to the applications of their research to human affairs. The findings of biology are so concrete and so pleasingly definite as regards rats and fruit flies that there is a tendency to apply them, lock stock and barrel, to the interpretation of the infinitely more complex existence with which culture has environed mankind. This pitfall has as a rule been avoided by the biologists themselves. They have realized, as Professor East points out so clearly in "Heredity and Human Affairs," that extreme caution must always be exercised. But the pseudo-scientific popular writer discovers in the results of biology ready material from which to fabricate the most ridiculous hash: the Nordic myth, for example; certain types of eugenic and psychological propaganda; some of which have done serious practical harm and all of which have served definitely to retard a proper appreciation by the intelligent public of the aims and the potentialities of those sciences.

Close association is needed between the several social disciplines and between that group and the biologists. But the theoretical desirability of such intercourse is naturally never going to bring it about. Every one is too busy tilling his own little patch. Only common interest in common problems can induce true intellectual understanding, active cooperation and the essential pooling of ideas.

How these things can best be accomplished I again do not know. But it is obvious that joint attack upon single fields by groups of workers representing many sciences may be expected to achieve vastly more significant results than the same number of individual studies prosecuted, as is usually now the case, in widely scattered fields. Adherence to this principle has led the Carnegie Institution of Washington to undertake its survey of Yucatan. Engaged in that project are archeologists, historians, sociologists; cultural, linguistic and physical anthropologists, physi-

ologists, epidemiologists, botanists, zoologists, geologists and climatologists. The survey is frankly an experiment, but it is based on the proposition that only by utilizing all possible resources can we expect to progress toward analysis of the vastly complex problems which face us in even so relatively simple an inquiry as that into the history and the present life of the Maya Indians. Further development of this closely coordinated type of investigation is evidently essential if we are to reach understanding of the infinitely more involved conditions which obtain in our own civilization.

Practically, we should doubtless get ahead much faster through such concentrations of effort. We might well expect more intelligent collection of data, clearer classification and sounder interpretation. But of even greater importance would be, I believe, the breaking down of the barriers which modern specialization has erected. Specialization, of course, is necessary, for it is the splitting up of something too large for immediate comprehension in its entirety to permit intensive consideration of its parts. The process, however, implies eventual reassembly of those parts and ultimate visualization of the whole. It is this broad grasp of man's biological make-up, his psychological endowment and his cultural overlay which must be attained if the social sciences are adequately to meet their ever-growing responsibilities. By making every effort to develop thoroughly well-rounded researches we can produce the best possible medium for the stimulation of synthesizing minds, and I am confident that under such conditions the humanistic Darwins and Einsteins will, in due course of time, appear to show us the way out of our difficulties.

I opened pessimistically, but I seem to have worked myself into a better frame of mind, and I close in the most approved Hollywood manner—a fade-out of a closely united scientific family with a whole litter of little super sociobiologists cooing in their cooperative cradles.

THE FUTURE OF MAN IN THE LIGHT OF HIS PAST:

THE VIEW-POINT OF A SOCIOLOGIST

By Professor WILLIAM F. OGBURN
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It is not yet given to the sociologist to see clearly into the future. And when he so ventures he can not see far. The astronomer looks with accuracy millions of years into the future, we think. The paleontologist's unit is large. The biologist's scale is the generation, but he knows that many thousands of generations may pass without appreciable biological change. The sociologist, however, is usually content to try to predict a few months ahead as, for instance, when the business depression will end, or who will be our next President.

When one looks into the future it is well to recall as a sort of precautionary measure the scant success that has been met by most of those who have been so foolish. For instance, that dean of science, Simon Newcomb, who could predict to the second a future eclipse of the sun, wrote in 1903, "The example of the bird does not prove that man can fly. . . . There are many problems that have fascinated mankind since civilization began which we have made little or no advance in solving. . . . May not our mechanicians . . . be ultimately forced to admit that aerial flight is one of that great class of problems with which man can never hope to cope, and give up all attempts to grapple with it?"[1] Yet just two months after Newcomb made this remark the Wright Brothers made their first flight at Kittyhawk, N. C. The scientist may be expected to err on the side of conservatism, but hardly H. G. Wells, who wrote in his "Anticipations," "I must confess that my imagination, in spite even of spurring, refuses to see any sort of submarine doing anything but suffocating its crew and foundering at sea." The fact that developments have occurred which these men said could not happen may be taken as an encouragement to be bolder. Yet few social scientists have ever so dared. I did hear, however, of some thirty-one predictions made before 1900 regarding the development of the ship,[2] only six of which materialized. But even so high a percentage of successes as this may also be taken as an encouragement to proceed. Perhaps my batting average will not be so high, and my predictions may be like those of Mr. Astor, who wrote in 1903 that "second story sidewalks, composed largely of translucent glass, leaving all the present street level to vehicles . . . will doubtless have made their appearance in less than twenty years."[3]

Yet there have been some responsible forecasts that have come true. Francis Bonynge,[4] for instance, predicted in 1852 the population of the United States

[1] Cited by Mark Sullivan in his "Our Times: The Turn of the Century," p. 366, from *The Independent*, October 22, 1903.

[2] Cited by Mr. Colum S. GilFillan.

[3] Cited by Mark Sullivan in his "Our Times: The Turn of the Century," p. 369, as appearing in the *New York World*, May 10, 1903.

[4] Francis Bonynge, "The Future Wealth of America," 1852, cited by P. K. Whelpton, "The Population of the United States, 1925 to 1975," *American Journal of Sociology*, p. 254, September, 1928.

50 years ahead, decade by decade, within an error of 5 per cent. Prediction in sociology deals with the environment of man rather than with biological man himself. Man has an unusual environment peculiar to himself alone and not characteristic of the lower animals. It is the environment which Herbert Spencer called the superorganic, which Tyler called culture, and which Wallas called the social heritage. With Eolithic man it must have been very small indeed, a little large in the time of Chellean man, growing slowly up to the last of the men of the old Stone Age. With Neolithic man it became much bigger and more rapidly growing, until in modern times it has become the great thing we call civilization in the largest sense of the term. The sociologist then looking into the future of man tries to see what is going to happen to the superorganic, this new environment peculiar to man.

Prediction in sociology rests on two methods. One is the simple extension of a trend line. But generally such a procedure is only approximately reliable for even a short time. If the trend is a sharply bending one, an extension of the curve beyond a few units of the scale may quickly take one into absurdities. Thus on this basis the ship in seventy-five years would be a mile long. The compound interest curve can not ever go very far in a real world.

The other method is the projection or consideration of the factors that determine the particular trend under consideration. For instance, the factors affecting the length of ships would be many, among them, length of docks and depth of harbor. Again the factors making population growth are immigration rules, growth of income, medical progress, diffusion of birth control, etc. So that by the extension of these factors forward in the form of birth rates, death rates, by age and social groups, and by other means, the curve of population may be projected forward.

In either case the shorter the extension of the curve the less wide the possible error. Projections are of course always in terms of the units in which they are plotted. Thus if the unit is a thousand years, then a projection of five units would mean a projection forward of 60,000 months, a very long time in months, but a short projection in units.

One curve that has been run back with indifferent success for around a dozen centuries is the curve of inventions and scientific discoveries. It is a curve bending so sharply upward as time goes on, that even if the inadequate records of the past get progressively worse and enormous numbers are lost, it is still thought that the line would be one curving upward.

The projection of this curve shows then for the future an increasing number of inventions and scientific discoveries. An analysis of some of the factors making the curve leads to the same conclusions. For instance, the number of inventions and the rapidity of their occurrence are functions of the number of elements in existence out of which inventions and discoveries are made. And generally inventions are not wholly replacements but additions to the total supply of elements. In other words, inventions and scientific discoveries are accumulative and as the pile accumulates, more and more inventions are made, since they do not appear to be restricted seriously by the limitations of human wants.

So in the future environment of man one sees an increasing number of inventions and discoveries, occurring with greater rapidity. This of course means change. It is customary for us to say that we are in a period of transition, implying that we are changing, amidst some confusion no doubt, from a more or less stationary past to some future condition of quiet and peace. The idea is that of a slope from one plateau to

another. But it is thought that this plateau toward which we are said to be moving is a fiction, the creation solely of a hope that looks forward to a haven of rest. But there appears to be no rest ahead for the conservatives, although the differences in the significance of the inventions seems to mean a somewhat undulating movement upward in the growth of material culture. Nations rise and fall, and peoples carrying a civilization shift their relative positions toward priority, but for the world as a whole the total variety of inventions has more or less steadily increased.

Man, the animal, has problems ahead in adaptation to this new environment of material culture. Each invention means a new problem of adaptation for mankind. Women have not yet adapted themselves to the tin can, although one of their adaptations in part was woman suffrage. Families have a problem in adapting themselves to contraceptives. We are not well adapted to factories. Our death rate is still greater in the newer cities than in the older rural cultures. So inventions mean social changes and problems of adjustment. The lower animals have a simple natural environment toward which to make an adaptation, as was also the case of early man. But modern man has a huge cultural environment to which he must adapt himself—a huge culture that is whirling through time, gaining size and velocity as it goes.

It seems to be something of a strain on the young infant to accomplish the feat of adaptation to this environment, judging by the numbers of problem children and the vast extent of mental disorders that follow. A young person used to get pretty well acquainted with his culture by the time he was fifteen or sixteen years old, but now infancy and education are prolonged and we find students in school until their late twenties or even later. In the future when the culture shall have grown much bigger and more complex, how shall this problem be met? Perhaps by prolonging infancy to, say, thirty or forty years or even longer?

More probably in the future there will be seen fewer attempts to learn it all and more attempts to learn only a part of what is to be learned. In other words, there will be specialists speaking a specialist's language; that is to say, a language not very intelligible to the non-specialists. It is said that even to-day some specialists, to wit, mathematicians and geneticists, have difficulty in understanding the language of some of their fellow specialists. But there will also be another language which these specialists all speak whatever their specialties may be. This language will be the product of the standardization and diffusion which follows upon the developing means of communication, that is to say the common language of the movies, the radio, the press, the advertisers, television, ready-made clothes, standardized goods, etc.

The great growth of communication through inventions in this field has the effect of negativing somewhat the aforementioned tendencies of culture to accumulate because it facilitates substitution instead of addition. For the earth as a whole communication is a leveling and simplifying process. Inventions in the field of communication then are some of the limiting factors that will prevent an exponential curve from being carried out in reality as it could be done on graph paper.

The society of the future then will be one of greater and greater change. And as the environment changes the habits of man change. Under these conditions morality, as it is generally conceived, will have no place. For the general notion of morality is the following of a set of rules or commandments. Such commandments can be laid down with

great specificity in a stationary society where experience leads to guidance in minute detail. But in a society undergoing great change there is little guidance to be gained from the past. The situations that arise are new, and ethical conduct is a matter of intelligence and forecast; and the fixity and detail of right and wrong give way before social expediency.

So also the attitude toward law will be very different. Our present ideal is that "the law is the law and it must be obeyed," though perhaps we do not live up to this ideal as well as did the Medes and Persians. But regrettable as it may be, law under a changing society can hardly have the force it has in a stationary society. Under a changing society it becomes very difficult to make rules that will last and hence that will be fully obeyed. It seems also inevitable that many rules, *i.e.*, laws, will have to be made, because of the velocity and bulk of culture. Some of these will be experiments and attempts to make men form new habits. So then the laws will assume less and less of a majestic nature. This does not mean of course that there will not be penalties; but rather that the divine element in them will be less and the human element more.

The technological progress, which will be advancing even more rapidly in the future, will of course not be confined to cities, but will spread to the countryside. Farm and factory joined together on the same land may well be in prospect. Where the foodstuffs grown yield by-products, factories for obtaining these by-products may be located near the farms, since electric power will be readily available. The folkways and manner of living among farmers will resemble more what they are in cities. Such is the magic of the newer methods of communication. Technological progress will mean, however, only a slight substitution of production in the chemical industry for production by the soil, sun and rain, since the latter are not so costly.

But the technical improvements will mean a greater efficiency for the food grower, so that fewer and fewer growers of foods will feed more and more consumers. And if population of the United States approaches soon the stationary point, then we may expect to see the sub-marginal lands turned back into forests, inhabited by wild game. But we shall hardly bring the Red Man back into his ancient home, though that would be scant justice.

It may also be that the cities will lose somewhat their identities. City limits are becoming less and less significant, being broken down by transportation systems and other similar agencies. The suburbs and the country immediately surrounding cities are highly urbanized, so that metropolitan regions are really replacing cities for certain purposes. In the future then the whole nation will become urbanized. There will of course be large centers where the density of population will be great, even though the easy distribution of electric power will occasion the growth of smaller centers. Man is a gregarious animal and the conditions of his future environment will give expression to this gregariousness.

It seems also very probable that the society of the future will have a somewhat different organization. Man, like the ants and bees, has a highly developed social organization, and in the future a still higher development is expected. The units of organization will tend to be much larger, due chiefly to the speed of transportation and the facility of communication over long distances. This statement is not to be taken as implying that the size of the physical plant will necessarily grow larger. There will of course be the greatest variety in the sizes of the

plants. The ultimate limit of this growth of organization is the world limit. Even among the smaller organizations unsuited to such development, there will be certain types that will be chained into much larger federations.

It may also be expected that the heterogeneity of the future material culture will call forth a great variety of organizational effort. The simplicity of the social organization of pioneer days is gone. Organization is a remarkable tool for getting things done and the law of survival will mean a great organizational development, despite some sacrifice of personal liberty and individualism, characteristics which may have a variety of other ways of expression, however. How these developments will affect the state is not clear. The tendency, however, seems to be toward larger organization, despite the setback occasioned by the Treaty of Versailles. One also thinks that a simple scheme like that of democracy will not be so successfully applicable to an actual distribution of power among the varieties of great organizations.

The growth of material culture does not mean that all property will be thus collectively organized. On the contrary, there is to be expected a multiplication in variety of smaller machines which will be personal property and on which the single individual will be dependent along with the multiplication of large machines found in factories on which man is so dependent. The pioneer to America required remarkably few fabricated objects, somewhat more, however, than the American Indian. But now man is dependent upon quite a variety: typewriters, fountain pens, mechanical pencils, tooth brushes, eyeglasses, radios, phonographs, refrigerating machines, stoves, watches, clocks, automobiles, golf clubs, books, scales, brushes, cigar lighters, cigarette cases, can openers, sunlight machines, etc., etc. It is clear that man has become more and more dependent on the smaller machines and tools and it is probable that the future will see the above list extended greatly. Pioneer settlement is increasingly difficult to-day because man must carry with him not only a great variety of tools, but also a great organization which will supply him with products from the big machines. The lower animals that migrate have no tool kit, primitive man had only a very small one, but modern man must take civilization along with him.

Technological progress means increase in the facility of transforming the products of the soil of the sea and the minerals into objects that fulfill man's wishes. Thousands and thousands of tools now do this work, and in great quantities because of the power from coal, oil, wind and water. These discoveries in power and new discoveries in raw materials that can be transformed will bring wealth and abolish poverty. Malthus saw the geometric increase in population, but he never saw the geometric increase in technology. The wealth or poverty of a people is dependent on three things: the status of technology, the supply of natural materials to be transformed into useful objects and the quantity of people to be supplied.

The future population has been much predicted. All are agreed, however, that the rate of increase in Western Europe and in America is slowing up. It seems probable that with the spread of the use of contraceptives the Slavic groups will also slacken in their rate of increase. The Orient and the backward peoples may increase more rapidly for a while but perhaps there, too, a slowing up is to be predicted. In fact, a declining population is altogether a possibility. So then with a restricted population, a rapidly growing technology and with perhaps a slightly growing base of materials

to be transformed, we should expect to be untrue the often quoted prediction of Jesus—"the poor ye have with you always."

If the use of contraceptives is extended radically, it will mean a revolution for women and children. There has often been discussion of how far the birth rate will fall. There is no numerical conclusion, but the answer is that the production of babies, like the production of potatoes, will be governed by the law of supply and demand. If the production of babies falls very low, the value of the baby will rise, according to sound economics. This appreciation of children will show itself in better kindergartens, playgrounds, schools. Apartment house owners will be glad to take families with children, but the valuation of children may be so great by that time that parents will not let them grow up in such a hostile environment as a modern city apartment. The domesticated animal usually has trouble with the breeding processes and man is no exception.

With a scarcity of children and the wealth that comes from technological progress, education in its higher branches will be much more nearly universal. The spread of higher education will be more rapid than the growth of vocational opportunities utilizing this educational content. The result will be that common laborer will be well versed in philosophy, and plumbers will discuss Aristotle—for they will still be quoting Aristotle—as well as members of the professions.

The scarcity of children will mean not only that they will be appreciated more, but that women who bear children will similarly be more highly valued. This increased value will command a price, and that price will be more opportunity. Under the circumstances society will be willing to adjust office and factory to part-time work, if indeed the hours of labor in the working day be not already short enough. Most of the differences in the social status of men and women can be traced to the fact that women not men bear children and rear them and as the birthrate falls these differences will be lessened. There are no peoples known even among primitive groups where there is not a division of labor between males and females, and it may be that some division of labor will continue to exist. But no society has had the reduction in the function of bearing and rearing children that the society of the future with its schools, nurseries, etc., will probably have.

The family organization will continue to lose in the functions it performs unless some new inventions are made that will bring industry back into the home. Electric power together with a multitude of electrical machines would seem to have the potentialities of restoring the home to its former magnificence, if it were not for the competition of industry outside the home. The overhead costs of home machines will be a factor that must be considered, as truly as the efficiency of factory production outside, which will continue to increase. It seems probable that the decline of the social rôle of the family will continue and that its chief functions will be affectional and in some instances educational. The stability of the family will then be as stable as affection is stable. And experience seems to indicate that affection is somewhat variable, at times even fickle. So separations and divorces are expected to increase even more than at present, particularly in the younger years of married life. But the family will hardly disappear. No primitive people has ever been found, no matter how low the scale of culture, that did not have a well organized family. Still, the society of the future may reduce the family functions a good deal more than is found among primitive peoples.

In the future there will also be a really great development of recreation. Man's capacity for recreation is enormous. But this great development will be encouraged because of the specialization of labor, the decline of superstitious religions, the menace of mental disorders and growth of economic surplus. It is recognized that there are various competing forces as in greed, in the love of power and in ambition. But they have not been for humanity as general a disciplinary force as hunger. So sports and recreations of all kinds are expected to flourish and to be the most serious hindrance to the spread of education among adults.

These then are some of the trends which seem probable to a sociologist, who necessarily sees the future of man in terms of the future of society. Spencer conceived of evolution as occurring on three planes, the inorganic, the organic and the superorganic. The superorganic is the subject of study of the sociologist, and he knows something about the nature of its growth and development. Somewhat, though not to the same degree of thoroughness, as the biologist knows the processes of the growth and development of the organic realm. The future of the superorganic can not be seen with comprehensiveness. Only here and there do the probabilities of trends seem well marked. The projection of these trends into the future have been made without considering biological evolution. And to a certain extent the changes in the superorganic are dependent upon the changes in the organic. For instance, if babies could be grown in bottles as biologists suggest as a possibility, this would not be without effect upon the family. The trends pointed out above would be accentuated. So also if the injection of a skilfully balanced proportion of secretions from the ductless glands would at once make a man a Christian, then endocrinologists would replace preachers and the evolution of religion would be profoundly affected. Or if biologists could discover some way of telling which normals carry defective genes, the effect would be profound for all society. But it hardly seems worth while to take time discussing the future of a society where men, say, are produced synthetically in a chemical factory, when the latter event is so remote and so improbable. There is, however, always the contingency that some biologist may come along and upset the predictions of the sociologists —but it seems more probable that it will be an inventor who will do it.

THE FUTURE OF MAN IN THE LIGHT OF HIS PAST:

THE VIEW-POINT OF A GENETICIST

By Professor E. M. EAST

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ANY serious claim to foresee what is actually going to happen to the human race at any future period is undoubtedly a pretension unworthy of a scientist. I say this in order that no one will make the mistake of believing this symposium to be an effort at prophecy, with the contributors posing as oracles. Such vision is given only to statesmen and to fundamentalists.

Estimates of probable trends based on past experience, on the other hand, have proved useful in all sorts of industrial pursuits. It would be possible to defend our undertaking, therefore, as an attempt to utilize available data in plotting the course along which mankind is moving, in order to determine, as nearly as may be, what lies a little further on; for it might then be possible to mark out a new course which would lead to a more desirable destination. Perhaps this sort of thing is what our worthy president had in mind when devising the program; but I suspect that he was subtly planning quite a different assembly, in the nature of a clinical experiment, with the audience and the speakers serving as material. It ought to work in this way. Every statement that is made should act as a small quantity of antigen injected into the cerebral cortices of the members of the society who have been kind enough to attend. The production of antibodies should take place immediately. In other words, each subject will start to think about the topic under discussion and will perceive at once that the speaker has overlooked all of the really important factors in his equation and hence has been led to announce decidedly erroneous conclusions. I am thoroughly in favor of such experiments and hope that this one will be successful.

The first point which each speaker has had to determine, I suppose, is the period with which to deal. We must decide how far into the future we shall undertake to extrapolate our curves. And if we select different dates this does not mean that conditions at the least distant one will be pictured most accurately. It depends upon what variables are chosen for consideration. An astronomer, dealing with a few precise laws of motion, may calculate eclipses a million years ahead with a high degree of confidence in the accuracy of his predictions; a politician has little chance of forecasting the probable course of the next election. The sociologist, therefore, can treat the near future most advantageously. The anthropologist can deal with more distant epochs. He has one of the attributes of deity—a thousand years in his sight are but as yesterday when it is past. The geneticist stands somewhere in between. Perhaps, for him, the year 2500 will serve as a convenient date. After all, the 570 years between then and now include only twenty generations or so—twenty new distributions of the genes.

What, then, will be the probable condition of the world in the year 2500?

Since there is but half an hour at my disposal, I shall confine my speculations to three points: (1) the population of the world and its genetic constitution; (2) the genetic philosophy to which this population may be expected to subscribe, and (3) the probable biological discoveries which have genetic aspects.

The population of the world should be about 3,500 millions, or twice the census figures of to-day. The last doubling took about 90 years; the next doubling may be expected to take about 500 years; and from this point on, there should be very little increase. This figure will seem small to the imaginative geniuses who predict that the chemist will abolish agriculture during the next century by producing all of our food constituents synthetically, or by growing particularly tender beefsteaks and delicately flavored lamb chops in huge vats of culture media. I regret being commonplace; but, having given considerable thought to potential sources of power and raw materials, to the efficiency of laboratory processes, and to other possible factors in the move toward annulling the operations of the Malthusian law, I can develop no greater enthusiasm over the romantic predictions of this type—as, for example, those of the Earl of Birkenhead[2]—than I can over a fresh announcement that Congress is going to investigate a new perpetual motion machine.

The chemist will undoubtedly perform many wonders in the near future. He will learn how to make the fibers, the drugs, the oils, and the other commodities which are to-day obtained from animals and plants. He will manufature vitamines and hormones. And he will be able to produce synthetic carbohydrates, fats and amino-acids. But with the exception of commercially hydrolyzed cellulose, these food products will be laboratory curiosities, for the chemist will be unable to obtain power and raw material at a sufficiently low figure to enable him to compete with the private factories run by the lower animals and the plants.

Though the average birthrate for the world as a whole will probably continue to fall during the next century, no matter what conditions are confronted, the difficulty of obtaining power at a low cost is going to be the determining factor in fixing the population limit and in setting the pattern of future civilizations.

The oil age will soon pass, and in 500 years the reserves of worthwhile coal will be running low. The ingenuity of man will then be taxed to the utmost to keep up with the demands for more and more power. No doubt he will solve the problem after a fashion, though there is no good reason to believe that he will solve it in a wholly satisfactory manner. It does not follow that because man has devised means for disposing quickly of Nature's gifts of fuel, he is thereby qualified to invent low-priced substitutes. The prodigal heir is not usually the perfect business man. The extreme difficulty of the task is apparent if we are not led astray by Birkenhead's nonsensical dream of unlocking atomic energy. There are just five prosaic possibilities—water, tides, wind, sunlight and earth-heat. Ordinary water power, when completely developed, can furnish less than ten per cent. of the world's needs. Mankind will have to fall back on the other four sources, and their utilization will require extraordinarily expensive mechanical equipment. I have no idea as to which source will be tapped, or how satisfactory the results will be, but I am convinced that any such method will be decidedly more costly than digging coal. Haldane puts his trust in wind, though this may be

[2] "The World in 2030," by the Right Honorable The Earl of Birkenhead, P.C., G.C.S.I., D.C.L., LL.D., D.Litt., N. Y., Brewer and Warren, 1930.

only a simple reflex due to reading the London *Times*.

For these reasons, it seems likely that the world will go on without the radical industrial revolutions which so many people fondly expect. Agriculture will probably continue to be the fundamental occupation of mankind for thousands of years, just as it has been in the past. The grave difference between the future economic situation and that of the present era will be due to the fact that agricultural efficiency per man-power is working toward the point where less than 20 per cent. of the world's inhabitants will be required to feed the rest. Industrialization must increase proportionately, therefore, in order to give occupations to the men released from farm work. If this process can go on as far as it is possible, theoretically, for it to go, then each person will be provided with more and more mechanical servants and will receive greater and greater quantities of material comforts. Personally, I am inclined to believe that this trend will have reached its peak before 500 years have passed, and that then a back-to-the-land movement will be required because industrialization will have reached a period of diminishing returns. If the population shall have approached a stationary condition before this date, no extraordinary economic dislocations are to be expected; but if the population should increase to the limits permitted by the earlier economic prosperity, it is unlikely that violent disturbances can be avoided.

Assuming that the population of the earth will have mounted to only 3,500 millions during the next 500 years, and that this increase will have taken place under a constant trend toward greater industrialization, what will be the situation from the genetic point of view?

As I see it, the world will be populated by hybrid mixtures of all kinds. Many relatively pure specimens of the yellow race will be found in eastern Asia, many similar representatives of the white race will be found on the other continents, and samples of the black race will be found in Africa; but, in the main, the inhabitants of the earth will be a rather heterogeneous lot. This process has been going on with increasing rapidity during the immediate past, and all signs point to a still higher velocity of the reaction in the immediate future.

In order to visualize this trend in undistorted perspective, we must take into consideration both the sociological factors and the artistic factors which have an influence in this direction.

It is especially important to realize that, though the world is likely to be supporting only 3,500 million people in the year 2500, it will probably have a population of about 3,000 million by the year 2100. At this earlier date, we may feel assured that all easily colonizable portions of the globe will have become fairly densely populated. Most of this expansion will be due to the efforts of the white race in Africa and in North and South America. In these territories the struggle for survival between the newcomers and the aboriginal inhabitants will soon grow more and more severe. As racial entities, the blacks and the Amerinds will then tend to disappear. Their remnants will be absorbed into the white race. In Asia changes will occur of like character though not of like degree. Asia already contains some 400 million of the so-called brown races, which are mixtures of at least two, and perhaps of all three, of the primary groups. Since they will probably be unable to gain any acreage which they do not hold to-day, we need not consider them further in this connection. But the yellow race will expand to the north and the west, if not to the south, and in this expansion there

will be a further tendency to unite groups having diverse genetic constitutions.

There are plenty of solid sociological impediments to happy interracial unions to-day; but really there are only two arguments that have a biological basis. There may be whole races that are vastly inferior to others. The members of the yellow and the white races believe that they outrank the black race as a whole. The more advanced tribes among the negroid group feel that they are immensely superior to the pygmies and negritoes. The Japanese look down upon that Caucasian remnant, the Ainu tribe. The Caucasians, as a group, recognize no equality with themselves among the poor relations of the Mongolians that they have met here in the Western hemisphere. And there is considerable evidence to support these beliefs. Second, it is possible that some races exhibit a genetic incompatibility with each other, which causes disharmony in the anatomy of the resulting progeny. Apart from these matters, interracial antagonisms are largely a matter of ignorance. Can one doubt that when the turn of a button on a perfected stereoscopic television radio apparatus will, for all practical purposes, put one in the physical presence of the art, the literature and the social customs of any given people, all mere prejudices will soon break down?

As I visualize conditions, then, long before the year 2500 the heterozygosity of mankind will have increased manyfold, with all the possibilities for the production of ultra-idiots and infrageniuses that such a mixture of genetic differences entails. One may assume that this situation will bring about some very important sociological changes, though what they will be is difficult to say. I do not believe that national aspirations will be weakened, for national solidarity is not built upon a basis of racial homogeneity or of lingual similarity, but rather upon tradition. Nor do I believe that a world union of any kind will be promoted. War will probably continue to be *the* great adventure of the human race. But, in order to gain full satisfaction from the radio-electric devices which will be in common use at this time, it will be necessary for every educated person to be conversant with a universal language. This will raise to the nth power the possibilities of that powerful tool which aligned nations against each other during the great war. I speak of propaganda. Imagine propaganda being spread to a thousand million television radios throughout the world in a language understood by every one. It is hard to say whether the gain in intellectual liberalism which will undoubtedly accrue to our descendants through better opportunities to become familiar with world conditions will more than offset the increased bigotry which will be induced by the vast number of lies which they will swallow.

You may ask how such matters relate to genetics. Perhaps the connection is not particularly close. Yet is it not true that propaganda available to every nation, indiscriminately, will be likely to break down whatever racial solidarity is left at this time? To-day English speech is a greater bond than English blood. An accepted Esperanto or Ido, together with a tenfold increase in racial hybridization, will help produce political alliances which are now quite unlikely.

Extended racial intermixture during the first part of our 570 years will prepare the way for a second development which has the highest genetic interest—the adoption of a eugenic social system, through necessity, as a move toward self-preservation.

Society has always been stratified. Until modern times, this stratification

has, nominally, had something to do with heredity, though its genetic basis was unsound. During the past few centuries, the division in the more enlightened countries has been economic. It, also, has been genetically unsound. Yet both of these arrangements—the feudal aristocracy and the capitalistic aristocracy—have had genetic value in a statistical sense. Havelock Ellis has shown that, during the last three centuries, the lower classes in England have produced a constantly diminishing supply of great men in proportion to their numbers. The great men rose from their classes like cream and, like cream, they were pasteurized.

Nations which have had a great deal of racial intermixture have developed more extreme caste systems. We need not point to India as an exemplification. We find a similar disposal of the population in the West Indies, in Mexico, in South America. It will follow, as the night follows the day, that an almost universal policy of racial amalgamation will beget an almost universal series of caste systems. We hope that they may be founded upon genetic principles. If they are, there is great hope for the future of the human race. If they are not, the situation is rather hopeless; for, no matter how little average difference in physical and mental worth there is between races, there is an immense spread between the best genetic constitutions and the worst genetic constitutions possessed by individuals.

I need not describe the eugenic philosophy which society might well adopt now, and which it must adopt later if racial decay is to be prevented. The laws of selective breeding are sufficiently well known to all who are here. But I must say a few words about the practical application of these laws in a eugenically-minded society.

I do not assume that society will apply a eugenic totem system to marriage and reproduction. It is unlikely that there will be one set of aristocratic gene-carriers and one set of proletarian gene-carriers who are not allowed to intermarry; for this would be both impracticable and unbiological. Instead, every effort will be made to adopt a flexible system which will encourage reproduction among the worthy of all economic groups and which will discourage it among the unworthy. It is probable that the discovery of tests for detecting carriers of defective genes will make the application of such a scheme easier than would be the case to-day. And even if it is impossible to develop such tests, it will not be so difficult as many people think to work out a policy having a reasonable degree of effectiveness. In a twenty-sixth century society science will rule. The intelligent portion of the population will then realize that it is as much their duty to have a certain number of healthy children as it is not to have any unhealthy children. The unintelligent portion can be kept in hand in other ways. It is only necessary for them to be made to understand that unscientific humanitarianism is a bygone relic of the twentieth century, and that public aid, suffrage and relief from taxation are forthcoming only if the eugenic ideals of the state are advanced.

I have no doubt that this type of proposal will sound silly to most of the members of the present generation; but if interracial hybridization becomes as wide-spread as I have pictured it, and if social sterilization of the fittest continues as it has in the past, nothing less drastic will prevent racial deterioration. This conclusion follows because of a genetic point which seems to have been overlooked by otherwise competent writers on the subject. It is this: Genes have no immortality *per se;* they must be kept in the living network of descent. It is quite true that if it takes

10,000 genes to produce a man, then as long as there are human beings, each individual will possess these 10,000 genes. But the difference between genius and stupidity may be due to 20 plus genes in the one case and to 20 homologous minus genes, in the other case, and there is nothing to guarantee that any or all of these plus genes will not be lost. It is by no means certain that the England, France and Italy of to-day—countries of which the United States is a biological part—possess all of the genetic potentialities which they had during the days of the Renaissance, or that Greece can have another Periclean Age when governmental conditions are favorable.

In this connection, let me cite a statement from a paper in the current issue of *Harper's Magazine*. Mr. Harold J. Laski, who is expert in many lines, discusses "The Limitations of the Expert" who is expert in only one line. The expert, says Laski, "too often, also, fails to see his results in their proper perspective. Any one who examines the conclusions built, for example, upon the use of the intelligence tests will see that this is the case. For until we know exactly how much of the ability to answer the questions used as their foundation is related to differentiated home environments, how effectively, that is, the experiment is really pure, they can not tell us anything. Yet the psychologists who accept their results have built upon them vast and glittering generalizations, as, for instance, about the mental quality of the Italian immigrant in America; as though a little common sense would not make us suspect conclusions indicating mental inferiority in the people which produced Dante and Petrarch, Vico and Machiavelli. Generalizations of this kind are merely arrogant; and their failure to see, as experts, the *a priori* dubiety of their results, obviously raises grave issues about their competence to pronounce upon policy."

This is too much, even from the professor of political science at the University of London. One would not expect Mr. Laski to have learned anything about the validity of results secured by the intelligence tests. In the first place, the work was done in great part by Americans; in the second place, Mr. Laski long ago took the stand that this phase of psychology is "the lunacy of a realist," in which he does not choose to believe. But one might expect the conclusions to exhibit a little more logic and a little less sentimentalism. Mr. Laski knows perfectly well that no psychologist has drawn any inference as to the mental capacity of the Italian nation from intelligence tests given to small groups of Italian emigrants. Such conclusions as have been drawn are concerned solely with the comparative ratings of the groups listed. But this is not the point to which I wish to draw attention. The most recent genius cited is a third rate historical philosopher of the seventeenth century. The other three are really great minds of the thirteenth, fourteenth and fifteenth centuries, and have a critical rating in the same order as their birth. Other names might have been cited. There is no gainsaying the preeminence of Italy during the Renaissance. But why has it not occurred to Mr. Laski that it is quite possible that the gene complexes which drew the pattern of civilization during this period are not now functioning in profuse quantities—in Italy, France or England, or, by the same token, in the United States? And the gentleman talks of arrogant conclusions!

Let us now take a few minutes to consider the biological fashions of this time 500 years ahead. Its most singular feature, according to Haldane, will be the production of ectogenic infants. In fact, Haldane's vision of incubating artificially fertilized human eggs on nutrient solutions has so intrigued

Birkenhead that he takes ten pages of prophetic scribble to discuss its possibilities. This is all very well. There is a reasonable expectancy that the thing may be accomplished. It is also a reasonable expectancy that mankind will discover how to induce parthenogenesis. But there are several good psychological reasons for thinking that neither of these processes will ever become popular. Woman will not relinquish the experience of motherhood just when science has made it easy for her; and man will probably rebel at being nothing but a figure of speech. I have great respect for biological chemists and other workers in applied biology, but I think that they will occupy themselves along other more practical lines. We may mention a few samples, for on this phase of future development predictions can be made with some degree of confidence.

We may assume that parasitic diseases will be practically eliminated. It is no mad optimism to feel that those infectious organisms which must have human hosts will be extinguished completely. But progress along this line does not mean that mankind will be freed from all fear of disease, or that the total span of individual existence will be greatly increased. During the next half-millennium, it is probable that the expectancy of life at birth will rise to sixty-five years or thereabouts; but there is no likelihood that the streets will be cluttered with doddering creatures of a hundred and fifty summers, as so many people hope. An increase of fifteen years in the average length of human life will be hard enough to attain, and will bring to the fore a sufficient number of difficult sociological problems; an increase of double this amount would dislocate society completely. And, no matter how efficiently parasitism is controlled, there will be plenty of troublesome pathological conditions remaining. In fact, new diseases will develop as industrial and sociological changes occur. No amount of progress in pathology will prevent our internal organs from wearing out; so that if we escape gout and rheumatism and cirrhosis, we shall drop of heart disease after ten years of senile dementia, anyway. Nevertheless, our descendants can expect a reasonably long life which is relatively free from disability, which will be a good thing for the individual. They must also expect that many will be born who ought not to have been born, and that many will live to reproduce who ought to die —which will be a bad thing for the group.

We may also expect to have various and sundry pills invented which will overcome the ill effects of non-functioning organs. What insulin has done for diabetes, we may expect idiotin to do for feeble-mindedness. We shall have ostin for cleft palate, optin for color blindness, epileptin for epilepsy, and so on down the list. We shall thus have a period in which we save so many defectives that they may breed double and triple defectives; that the chief occupation of humanity will be dosing one another.

I am inclined to believe that these medical and chemical discoveries, coming thick and fast, will, indirectly, be the means of bringing the human race to see the essential soundness of eugenic philosophy. It will become absolutely necessary to call a halt on all blindly humanitarian impulses, and to adopt a wholly new policy. Such discoveries as I have just described will make it apparent to every one that natural selection can not be balked at every turn without serious consequences. They will make our descendants "eugeniconscious," as writers of advertising copy would say.

Again, we shall learn to synthesize

the various hormones. This advance, like all the others, will have both its advantages and its disadvantages. Much good will come from it when we learn how to supplement nature in a sensible way, a way that will bring about a fuller, happier life. But one foresees trouble ahead, with near-Methuselahs of both sexes ranting around in quest of a second dispensation of youth, until such time as they learn that the peace and quiet of a dignified old age has its favorable aspects.

Another change that is virtually certain to come is the control of reproduction in a strictly biological way. One may expect to see such methods perfected within the next half-century. There are several possibilities. I am inclined to think that the most practical will be the control of ovulation. If this device has any disagreeable psychological effects, then ways will be found for producing spermatoxins or for sterilizing the male temporarily.

One might continue to speculate thus almost indefinitely. And it is an amusing pastime which does no one any harm. Moreover, some such changes as we have outlined are certain to take place, though we can not describe them with any great precision. It is a pity that we can not return to see just what they are.

THE AGE OF THE EARTH—RADIOACTIVITY METHODS OF ITS DETERMINATION[1]

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Introduction

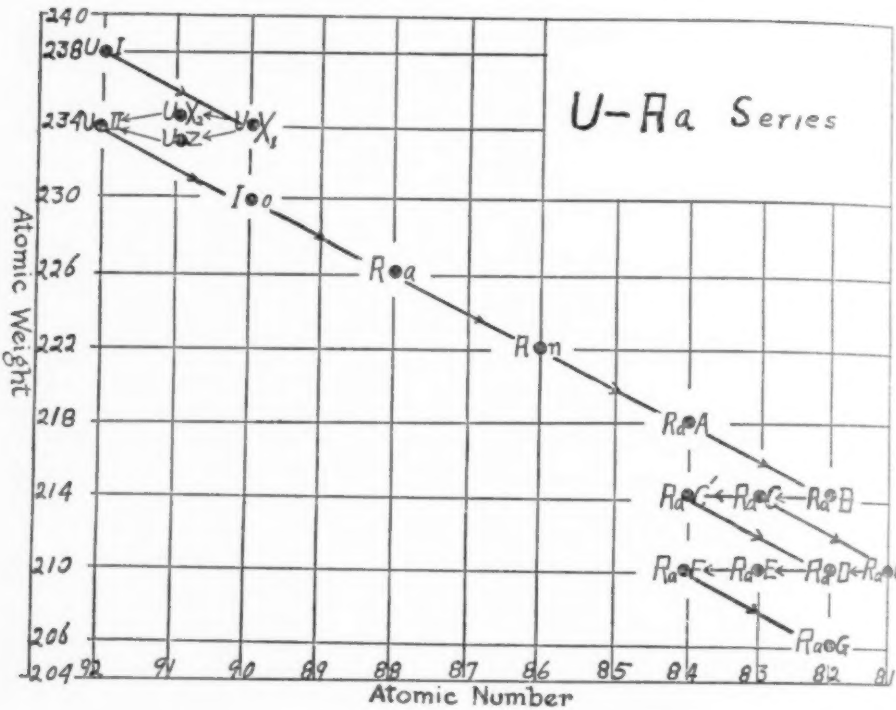
Various attempts have been made to estimate the age of the earth. We may refer to the methods used as astronomical, physical or geological depending upon the hypotheses and data involved. They are all useful scientifically in that we gain some basis of assurance that the underlying hypotheses may have some truth in them if by considering the same "age" they give reasonably concordant results. In the problem of the "age of the earth" it is essential that we have a clear conception of what the term "age" means in any particular case, otherwise apparently discordant results may lead one to condemn unjustifiably both the results and the methods, whereas the chief source of difficulty may be in the fact that measurements are made from very different starting points.

In the astronomical problem the age may mean the time that elapsed since the earth separated from the sun and this in turn involves the hypothesis that the earth did separate from the sun and the manner in which it may have happened. In the physical problem proposed by Kelvin it is the time that elapsed since the crust began to solidify and this involves the hypothesis of cooling. The data involved are the original temperature and the rate of cooling. Kelvin's handling of the problem left little to criticize in the method itself until we learned that radium is found in practically all materials of the earth's crust and that the rays emitted by radium produce heat when absorbed. It was then learned that the earth should be getting hotter instead of colder if radium were distributed throughout the earth in quantity averaging per unit mass the amount found as an average in the surface materials. Evidently, we are confronted with the necessity of greater experimental knowledge about the temperature, the pressure and the constitution of the interior of the earth in order to make this method really useful. In the geologists' problem the age is called by them geologic time, *i.e.*, the time that elapsed since the beginning of the oldest known formation. This age is subdivided into various subdivisions and it is of great interest to the geologist to get the lengths of these subdivisions in years. The geologists for more than a century have followed a sound principle in estimating this age, namely, by studying the extent of the existing formations and the rate of production (and also destruction) of similar rocks as the process is going on to-day. There are many difficulties encountered in these studies and the probable error is quite great; nevertheless, when all things are considered the order of magnitude of the age obtained should be correct.

Radioactivity

Confining our problem to the limits set up by the geologist we may hope to

[1] At the request of the editor the author prepared this popular presentation of the radioactivity methods. It is based on a part of his work which was the outcome of cooperative work of the subcommittee of the National Research Council. This committee has now in the course of publication a bulletin entitled "The Age of the Earth" and contains parts written by the individual members. The committee are Ernest W. Brown, Arthur Holmes, Alois F. Kovarik, A. C. Lane, Charles Schuchert, and Adolf Knopf, *chairman*.



get a reasonable answer to our question about the age of a geological formation by studying the radioactive minerals in such a formation. We shall see that one of the radioactivity methods presents a great probability of success in estimating the age of the formation by deducing the age of a primary radioactive mineral from the formation. A radioactive mineral is so called because it contains radioactive substances. A radioactive element, *e.g.*, radium, is an element whose atoms disintegrate and change into atoms of another element and the disintegration of the atom is accompanied by emission of a radiation from the disintegrating atom: either (1) an alpha ray which has been proven to be the nucleus of a helium atom or (2) a beta ray which has been proven to be an electron and either of these radiations may be accompanied by a third radiation, an electromagnetic radiation, called the gamma ray. The emission of the alpha ray or of the beta ray constitutes the basic change in the constitution of the nucleus of the atom so that when the remaining material parts and energies are rearranged to be in equilibrium we have a new atom lighter in weight and of a new nuclear constitution and possessing new chemical properties. This phenomenon of disintegration noticed in the case of these elements is called the radioactivity of the element and the branch of science embracing these and related phenomena bears the name of radioactivity.

The fundamental quantitative law of radioactivity may be stated as follows: the rate of disintegration depends on the number of atoms and on the nature of the radioactive element and the ratio of the number of atoms disintegrating per second to the number of atoms of the radioactive element equals a constant which constant is different for each radioactive element and, therefore, char-

acterizes the radioactive element. These constants are known for the various radioactive elements. In symbols the law may be given as follows:

$$\frac{\frac{dN}{dt}}{N} = -\lambda$$

where $\frac{dN}{dt}$ represents the number of atoms disintegrating per second; N, the number of atoms; λ, the characteristic disintegration constant of the particular radioactive element under consideration and the minus sign indicates that N decreases in value with time. If N_0 is the number of atoms at the beginning and N the number after some time t, then by integrating the above expression we get a relation between N and N_0 as follows:

$$N = N_0 \varepsilon^{-\lambda t}$$

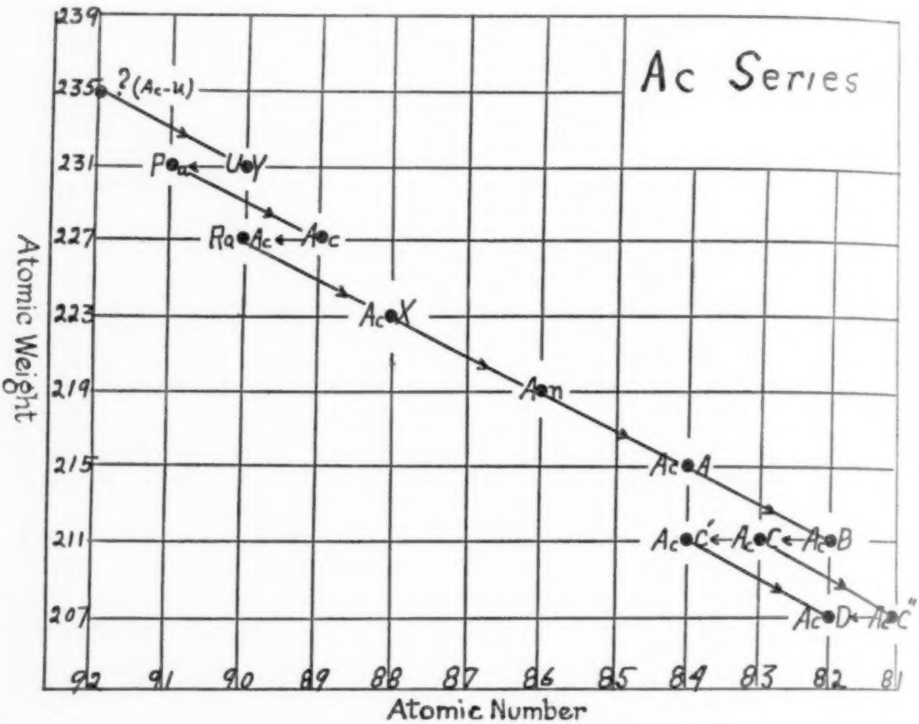
where ε is the base of the Naperian (or natural) logarithms. This relation connects the amounts of a radioactive substance at the beginning and at the end of an interval of time. We see, therefore, that the phenomenon of disintegration of a radioactive element furnishes us, so to speak, a clock by means of which time can be measured. We shall later refer to this matter.

An atom which has disintegrated leaves behind matter and internal energy which, after rearrangement of its parts, becomes the new atom. This new atom may likewise be radioactive and it is found by studying all the radioactive elements known that they can be arranged into three series, called the uranium-radium series, the actinium series and the thorium series. The head of the uranium-radium series is uranium I, of the actinium series it is actino-uranium, and of the thorium series it is thorium. Every radioactive atom within any one of these three series is formed from the atom preceding it in the series and it follows, therefore, that when one atom of the head of a series disintegrates there will be formed in due time one atom of every one of the radioactive elements of that series and that ultimately one atom will be formed of that product into which the last radioactive element of the series disintegrates. In the uranium-radium series the last radioactive element of the series is polonium, and its atoms disintegrate into atoms of a non-radioactive element called radium G. The ultimate non-radioactive element of the thorium series is called thorium D and of the actinium series, actinium D. The non-radioactive end products of the three series are all isotopes of ordinary lead.

Isotopy and Atomic Structure

It seems expedient to digress a little more at this time and make clear the meaning of isotopes, inasmuch as the method to be described as the best radioactivity method for the determination of the age of a radioactive mineral demands a knowledge of the isotopes of lead. Mendeléeff arranged the known chemical elements in a periodic system according to the chemical properties of the elements. There was one element for each place (excepting those places for which elements had not been discovered). When Boltwood announced the discovery of ionium, the radioactive element whose atoms after disintegration form atoms of radium, he also announced the important fact that ionium and thorium have exactly the same chemical properties and that he could not separate them from each other by any known *chemical* means, *i.e.*, ionium and thorium, once mixed, were found to be chemically inseparable.

This work of Boltwood indicating two elements in the same place in Mendeléeff's table formed the basis of much further investigation by chemists and physicists bringing forth other discover-



ies of a similar character and ultimately leading to the establishment of the new branch of science, called Isotopy, which is so important in to-day's physical and chemical researches. The word *isotope* was coined by Soddy, who contributed much to the subject, and is derived from two Greek words *isos* and *topos*, meaning same place, and designates elements which have the same chemical properties and occupy the *same* place in the periodic table.

The researches in other fields, particularly in the study of the Röntgen rays and the scattering of alpha rays by the atoms of various elements, have brought forth very important results bearing on the structure of the atom and on the position of the elements in the periodic table. We can not go into these researches here but a few of the conclusions from them should be noted in order to understand the diagrams given for the radioactive elements.

The first general conclusion concerns the general structure of any atom. It is due to Rutherford and to Bohr. Any atom has a central portion called the nucleus which possesses nearly the whole mass of the atom, which is very small compared to the size of the atom and which is electrically charged positively. Outside the nucleus are the negative electrons, as many in number as are necessary to equal the positive charge of the nucleus to make the atom neutral, moving in some kind of orbits and are located in definite "energy levels." If an electron has left its particular energy level, for any reason whatever, and some other electron from outside the atom or from some energy level outside of the one in which there is a "vacancy," then during this transition of the second electron, and due to it, a radiation of visible or invisible light is emitted by the atom and its wave-length is a definite one and depends on the amount of

the change of the energy levels. This forms the basis for the modern theoretical spectroscopy. The electrons in the part of the atom outside the nucleus are also responsible for the "valency" of the elements in chemical combinations.

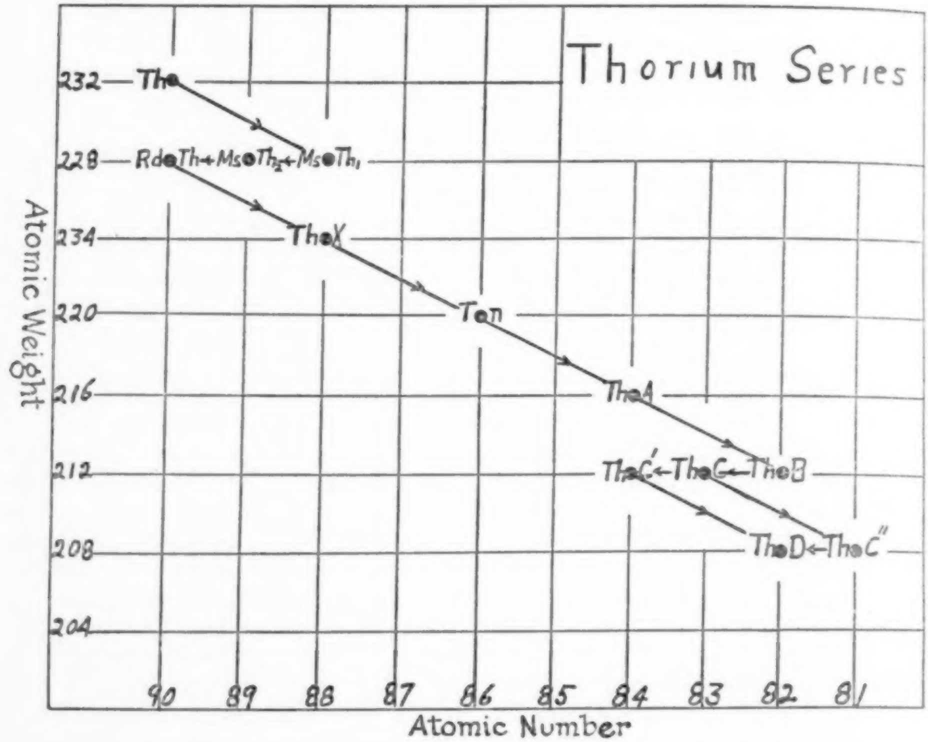
Later the work of Moseley on characteristic x-rays of various elements and that of Chadwick on the scattering of alpha particles by atoms of copper, silver and platinum showed a connection between the charge of the nucleus and the position of the element in the periodic table. If we take the electron (positive or negative) as the unit of charge of electricity, then this relation is that the number of the electron units of charge of the nucleus is the number of the position of the element in the periodic table, *i.e.*, if e represents the charge of electricity, properly called the electron, 1e, 2e, 3e, ---- 29e, ---- 92e are the respective charges of the nuclei of hydrogen, helium, lithium, --- copper, ---- uranium and the numbers 1, 2, 3, -- 29, -- 92 represent the positions of these elements in the periodic table in which they are arranged according to their chemical properties, beginning with the lightest, the hydrogen atom and proceeding to the heaviest, the uranium atom. The numbers, 1 to 92, are called the atomic numbers. Incidentally, these numbers also give us the number of (negative) electrons in the part of the atom which is outside the nucleus.

The second important fact which we must note is the Displacement Law and this concerns the positions of the radioactive elements in the periodic table. The law is due to Soddy and to Fajans. It was obtained by studying the chemical properties of radioactive elements and placing the elements in the periodic table. It was then found that after the disintegration the new atom which was formed occupied a place in the periodic table whose atomic number was smaller by two or larger by one than that of the disintegrating radioactive atom, depending upon the fact whether an alpha ray or a beta ray was emitted. On the present knowledge of the atomic structure, this is comprehended when we bear in mind that if the alpha ray leaves a nucleus, the positive charge of the nucleus is made smaller by plus 2, namely the double positive charge of an alpha particle, and if the beta ray (electron) leaves the nucleus, the positive charge of the nucleus is made smaller by minus 1, namely the negative single charge of an electron, *i.e.*, it becomes more positively charged by one unit. Hence, the atomic number in the former case is two less than that of the disintegrating atom and in the latter case it is one more. Since the atomic number is also the number of the element in the table it explains the position of the new radioactive element formed after disintegration.

The atomic weight of the new atom is less by the loss by radiation and this is approximately 4 units less when an alpha ray is emitted and is negligibly less (electron's mass being small) when a beta ray is emitted. These considerations will help in understanding the charts giving the atomic numbers and atomic weights which are given only as whole numbers.

It will be noticed that the end products—the non-radioactive elements—of the three series, radium G, actinium D and thorium D, respectively, are all of atomic number 82 which is also the atomic number of ordinary lead. They are the isotopes of ordinary lead. Their atomic weights are, respectively, 206, 207 and 208, while that of the ordinary lead is 207.2.

It is to be noted, therefore, that the chemical processes which separate ordinary lead from the mineral will simultaneously separate all these isotopes, if present, with the ordinary lead and the



lead so obtained will be a "mixture" of all of them with an atomic weight depending on the amounts and the atomic weights of the various constituents.

Radioactive Methods of Calculating the Age

The Helium Method: There are three proposed radioactive methods of determining the age. The oldest is referred to as the helium method. It was first proposed by Sir Ernest Rutherford, in 1904, in an address before the International Congress of Arts and Sciences in St. Louis. Helium is found in every radioactive mineral, in fact terrestrial helium was discovered in such a mineral. It is the result of the accumulation of alpha particles emitted by the various alpha ray emitting radioactive elements present in the mineral, and each of these alpha particles is the nucleus of a helium atom and on capturing a couple of electrons becomes a helium atom. It is evident that if we know the amounts of alpha ray emitting elements present and also their disintegration constants and the total amount of helium in the mineral, we can calculate the time it took to accumulate this amount of helium. However, helium being a gas, there is a great probability of loss by leakage, and the calculated time can, therefore, represent only a "minimum" age of the mineral. It may be of interest to note that the Berlin physical chemist, Paneth, recently applied this method in studying meteorites. The age he deduced for these extraterrestrial visitors to our earth is of the order of 2 to 3 billion years.

Pleochroic Halo Method: Another radioactivity method is based on the coloration of pleochroic halos found, for example, in biotite and fluorspar. It is due to Joly and Rutherford. It has

been shown that in general the radii of the halos correspond to the ranges of the alpha particles from the radioactive substances imprisoned with the central inclusion, which is generally zircon. The coloration is an effect of ionization by the alpha particles. If we irradiate the same material which contains the halos, *e.g.*, mica, with alpha particles from a known strong source and allow this to go on until the same shade of color is produced in the mica as is found in the halo, then the product of the number of alpha particles incident and the time of irradiation will equal the product of the much smaller number of alpha particles emitted from the inclusion in the halo and the geological (long) time to form the halo. The geological time can be obtained if we can estimate the strength of the radioactive element in the halo, provided, also, no other agent alters the coloration during the geological time. The fact is that it has been shown by experiments that both heat and prolonged ionization can alter the color—even producing "bleaching." Furthermore, the amount of radioactive material in the inclusion can not be accurately determined. Consequently, the method is not accurate nor dependable for age determinations.

Boltwood's Lead Content Method: The third method is one which offers the greatest promise of success. It is due to Boltwood.[2] Boltwood discovered, in 1907, the radioactive element *ionium,* the parent of radium, in his attempts to find proof of the disintegration theory of Rutherford and Soddy (advanced in 1903). He also gave attention to the ultimate disintegration products of the uranium-radium series and observed that all minerals containing uranium also contained lead, and came to the conclusion that lead was the final disintegration product of uranium. This was the first time that the idea was advanced that the final disintegration product of the uranium-radium series is lead. He found, however, that the amount of lead per gram of uranium in the mineral varied in different minerals. He arranged the minerals according to the lead-to-uranium content and drew attention to the fact that the increasing value of the ratio corresponded to the increasing age of the geological formation in which the mineral was found. To get this "age" expressible in years he assumed all of the lead to be the result of the disintegration of uranium. Knowing the rate of disintegration of a known amount of uranium, the rate of formation of the lead becomes known, and the age can be obtained.

In order to understand the process of reasoning that Boltwood followed—and this is necessary if we are to understand the complete method given below—let us assume a primary mineral containing originally only uranium as a radioactive substance. Let it be understood that no alteration of the mineral has taken place, except such alteration as is due to radioactive changes. The chemical analysis of such a mineral will give us the present amount of uranium in it and also the amount of lead per given amount of the mineral (generally expressed per 100 grams mineral). Knowing the present amount of uranium and the disintegration constant of uranium we could calculate the original amount of uranium if we knew the time elapsed, *i.e.*, the age of the mineral—or we can express the number of uranium atoms which disintegrated during that time in terms of the time by using the equations given above. Now, every atom of uranium which disintegrates becomes ultimately an atom of the end product, radium G. If this end product is the lead found—as Boltwood sup-

[2] **Bertram Borden Boltwood (1870–1927), professor of radio-chemistry, Yale University. See memoir in *American Journal of Science*, 1928, or forthcoming memoir of the National Academy of Sciences.**

posed—we can tell from its amount the number of its atoms and this number must be equal to the number of uranium atoms which disintegrated. Hence we can put the number of atoms of lead equal to the expression giving us the number of uranium atoms disintegrated —an expression involving the known amount of uranium found, the known disintegration constant and the *unknown time* during which the disintegration took place. This equation can be solved for the time. This is correct and would be sufficient were it not for the fact that every radioactive mineral contains radioactive elements of all the three series, and may have contained originally (and therefore also at the time of the analysis) ordinary lead for the same reason that it contained uranium. That end products of the three series are isotopes of lead was shown by Richards, Hönigschmid and other noted chemists.

Complete Solution

It is, therefore, evident that Boltwood's simple calculations of the age of the mineral must be modified to take into account the above-mentioned facts. The importance of taking thorium and its end product into consideration was soon realized because a vast number of uranium-bearing minerals contain also an important amount of thorium. Regarding actinium we knew too little of its real origin until about a year ago, but it now seems certain that the actinium series originates in an isotope of uranium, called actino-uranium, and that its end product is of an atomic weight 207, whereas radium G is 206, thorium D, 208, and ordinary lead, 207.2. Most of the calculations made, heretofore, ignored the presence of ordinary lead and disregarded actinium D, with the result that some confusion has been brought about. It is certain that the pitchblende from Jachymov (Joachimsthal, Czechoslovakia)—the mineral in which Madame Curie discovered radium—may contain ordinary lead because ordinary lead occurs in the same veins from which the pitchblende is obtained. If this is true of a particular pitchblende, why should we assume that it may not be true of other pitchblendes, except as to the amount of the ordinary lead?

With regard to actinium D it was supposed to be only 3 per cent. of radium G since actinium to uranium ratio in some minerals, accurately determined, show this ratio and actinium was supposed to branch off the uranium and, therefore, actinium D and radium G would be formed at these relative rates. Since the recent evidence points to the origin of the actinium series from an independent isotope of uranium, actino-uranium, whose disintegration is much more rapid than that of uranium, it is evident that the amount of actinium D, compared with the amount of radium G, may be much greater than 3 per cent. and will be greater the older the mineral. For these reasons the formulation of the basic equations which will give us the time, *i.e.*, the age of the mineral, must take regard of the possible presence of ordinary lead as well as of actinium D.

The basis for the formulation of the necessary equations is given in words by stating the following three fundamental facts:[3]

I. The sum of the masses of radium G (atomic weight, 206), actinium D (atomic weight, 207), thorium D (atomic weight, 208) and ordinary lead (atomic weight, 207.20) equals the mass of lead of atomic weight, A, found in the mineral.

II. The sum of the number of atoms of radium G, actinium D, thorium D and ordinary lead equals the number of

[3] A. F. Kovarik, "Basis for the Calculation of the Age of Radioactive Minerals," *Am. J. Sci.* [5] 20: 81–100 (1930).

atoms of lead of atomic weight, A, found in the mineral.

III. The number of atoms of the parent substance, disintegrating in each of the above cases, results ultimately in the *same* number of atoms of the end product, which is an isotope of lead.

These three statements can be put into the form of algebraical equations. The third statement will give the number of atoms (or mass, if desired) of the end product in terms of the number of atoms (or mass) of the parent substance found in the analysis and in terms of the time. It is in the equations derived from this statement that "time" enters into all of our equations and into the final formula. It is here that the "radioactivity clock" measures the time during which the observed changes of uranium atoms into radium G atoms, of actino-uranium atoms into actinium D atoms and of thorium atoms into thorium D atoms take place, and these changes are put into a quantitative form by the first two statements. The parent substances are uranium, thorium and actino-uranium. The first two can be readily determined by the chemical analysis of the mineral; the actino-uranium, being an isotope of uranium, presents difficulties of direct determination but can be determined indirectly by measuring the ratio of the amount of actinium (which would be in a radioactive equilibrium with the actino-uranium) to that of uranium.

Consequently, when a proper primary mineral is chemically analyzed and for a known amount of the mineral the amounts of uranium, thorium and lead are determined and in addition the atomic weight of the lead and the ratio of the actinium to uranium are also determined, then with the further knowledge of the atomic weights and the disintegration constants of the radioactive elements, our equations make it possible to obtain time, the age of the mineral, and also the amount of ordinary lead.

It may be surprising to learn that although age calculations have been going on for twenty years, yet there is not a single case of a mineral for which we have a complete set of data. We have many giving us the relative amounts of uranium, thorium and lead but no atomic weight of the lead. We have a certain number of excellent analyses which include the atomic weight determination but which lack the actinium to uranium ratio;[4] while those giving excellent determinations of this ratio lack all the rest of the data. It would seem, therefore, that while we have the means of obtaining an answer to our problem, we lack some of the data necessary for a complete solution. It is evident, therefore, that further work on the analyses is necessary and that these analyses should be made on the same specimen and a complete set of data should be obtained. However, we can circumvent the difficulty and obtain a fairly accurate determination of the time and yet take into account the possible presence of ordinary lead and reasonably accurately also account for the actinium D. This can be done since the atomic weight of actinium D is nearly the same as that of ordinary lead. It is done by considering the actinium series as if it were a branch off the uranium radium series—as was supposed to be the case until very recently. In this case the term involving radium G will involve a part of actinium D and the term involving ordinary lead will involve the rest of the actinium D, except for the error brought about in the number of atoms (atomic weight, 207.2) used instead of some other number of atoms (atomic weight, 207). Because

[4] A. F. Kovarik, "Actino-uranium and the Actinium to Uranium Ratio," *Science* 72: 122–125 (1930).

the amount of actinium D is not nearly so large as radium G, the error so introduced is not large. The equations set up for this case will involve only such data as we possess at the present time. The formulae can be put into practical form for numerical solutions. Applied to the two oldest minerals, namely, a uraninite from Keystone, South Dakota, and to a uraninite from Sinyaya Pala, Carelia, U. S. S. R., we obtained, respectively, 1,465 million years and 1,852 million years for the ages of these two minerals. Various uranium-bearing minerals from Norway give values ranging from 825 to 986 million years. It may be needless to add that when we have a complete set of data the equations derived from the above three statements of facts furnish the correct solution of the problem of the age of the mineral. The 1,852 million years represent a minimum measure of the age of the earth. The ages of the other minerals are, of course, in no conflict with this value because they represent the ages of respective formations which are geologically younger.

WHAT IS NEW IN MATHEMATICS?[1]

By Professor EDWARD V. HUNTINGTON
HARVARD UNIVERSITY

To ask "What is new in mathematics?" may seem to many of you like a foolish question. How can there be anything new in mathematics? How can two plus two be anything else than four? How can there be any new changes in so old a subject as mathematics?

Well, in one sense mathematics does not change. Whatever is once established as a mathematical truth is true for all time. The Pythagorean theorem about the square on the hypotenuse of a right triangle is just as true to-day as it was in the days of Pythagoras, twenty-five centuries ago, and it will remain equally true twenty-five centuries hence. Once true, always true, in mathematics; and in that sense, mathematics does not change.

But in another sense mathematics is changing enormously and with astonishing rapidity. New mathematical truths are discovered every year. The old truths are not discarded, but whole new branches of mathematics are constantly being developed. Mathematics is no longer a single science, but rather a great collection of sciences, so vast in extent that no one man can hope to master more than a small fraction of the field. The growth has been so rapid that even expert mathematicians working in different branches may be entirely ignorant of other mathematicians' results. No science is expanding more rapidly in the modern world than the old, old science of mathematics.

When the present president of Harvard University was a student in college he could take, and did take, every course that was offered in mathematics, on top of all the regular courses required for a general education. To-day, the mathematical courses offered at this one university would take seven or eight years of continuous work to complete, and even all these courses would give merely an introduction to the vast realm of mathematical knowledge. In every civilized country flourishing mathematical societies, whose total membership runs into tens of thousands, are actively pursuing the newest developments in advanced mathematics, and scores of mathematical journals are devoting themselves exclusively to the publication of these new discoveries.

A few decades ago, the high water mark of a university course in mathematics was the differential and integral calculus, and only a few exceptional students ever dared to rise to such dizzy heights. To-day the calculus is merely the starting point in college mathematics. In Harvard University alone over 500 students elect a course in calculus every year—most of them in their freshman year. In the country at large there are probably half a million people who have studied the calculus, and half a million more who appreciate how valuable a knowledge of the calculus would be to them if they had it.

What a change this is over a century ago! Mathematics is no longer regarded as hopelessly difficult; and students who specialize in mathematics—even in its higher branches—are no longer regarded as hopelessly "queer." What is the reason for this change? A large and increasing number of people have discovered two things about higher mathematics; first, that it is useful, and, second, that it is beautiful. When any branch of study is found to be useful and beautiful, it is bound to become popular.

[1] A radio talk presented under the auspices of The National Research Council.

First, mathematics is useful.

Of course as far as the elementary branches are concerned, the usefulness of mathematics has long been admitted. Every one who makes out an income-tax return recognizes the necessity for a little knowledge of arithmetic. Also elementary geometry and trigonometry have long been recognized as useful tools for the designer, the surveyor and the navigator.

But in regard to the higher branches of mathematics, it is only in comparatively recent times that their usefulness has been appreciated.

The extraordinary development of engineering in the present century has called for a wide-spread use not only of the calculus, but also of higher branches, such as the theory of functions of a complex variable, the theory of differential equations, and the extremely modern theory of integral equations, all of which had been originally developed without the slightest idea of their use in technology.

The famous electrical engineer, Charles P. Steinmetz, was twenty years ahead of his time in urging the need for more and higher mathematics in engineering; to-day, the growing importance of higher mathematical training for researchers and designers in engineering is constantly emphasized by the leaders of the great industrial corporations. Pick up any recent volume of the *Transactions* of the American Institute of Electrical Engineers, for example, and note the great mass of mathematical symbols that appear on almost every page. Mathematics pays, in dollars and cents.

In modern physics, there is so much mathematics of a very advanced character that it is hard to draw the line between what is physics and what is mathematics. For example, the Einstein theory of relativity is essentially a combination of non-Euclidean geometry and tensor analysis, both of which are branches of pure mathematics.

Without the results of mathematical physics, which is mostly mathematics, our present-day, long-distance communication signals would be impossible. You all know how the first long-distance submarine cable was a failure because of faulty design, and how Lord Kelvin improved the design and made the cable a success. He was able to predict the success of his design on the basis of purely mathematical computations. These computations were in fact so mathematical that the engineers at that time could scarcely believe the result, until they actually saw it work.

Again, in the field of long-distance telephony, mathematics has led the way to inventions which have greatly increased the distance the voice can be carried over a wire of given size. If it were not for mathematics, you could not send a long-distance telephone message to-day. And as everybody knows, the development of the radio itself, to which you are now listening, has been directly dependent on mathematical-physical researches of the most advanced sort. A recent text-book on radio makes the significant remark that the more easily the student can think mathematically, the greater are the possibilities ahead of him, in the science of radio.

Moreover, chemistry, biology, geology and even economics are coming more and more to realize that the rate of progress in these fields, under modern conditions, is directly proportional to the amount of mathematics that they use. A very brilliant medical man, whom this and other countries delight to honor, told me the other day that it is quite impossible for any one to keep up with recent developments in physiology without a much more extended knowledge of higher mathematics than it was possible to obtain when he was in college.

Even in the world of business and finance, the most recent mathematical theories on the analysis of statistical

data are proving to be indispensable to progress. For example, the successful installation of the dial system in telephone exchanges would have been impossible without the application of the most recent advances in the theory of probability. Stock-market forecasting is another field in which more and more mathematical theory is being applied. The mathematician of the future, instead of solving silly puzzles about "how old is Ann," may be using higher mathematical equations to figure out the next swing of the market!

The first reason, then, for the changed attitude toward higher mathematics is the enormous extension of its usefulness in practical human affairs.

The second reason for the new popularity of mathematics is more vital and more powerful. Mathematics is not only useful; it is also extremely beautiful. The beauty of a mathematical result is the fundamental motive for its pursuit. Every creative mathematician is essentially a creative artist. The most important and fertile discoveries in the whole field of mathematics have been made by men who were guided by esthetic motives—men whose insight into unsuspected relations between apparently diverse phenomena led them to replace an ugly and unsatisfactory chaos by a beautiful and illuminating order.

That is the great secret of mathematics—its power to reduce the complex to the simple. Every branch of higher mathematics enables us to survey, as one simple whole, a vast number of seemingly complicated and unrelated facts. Mathematical notation appears complicated only because it is really so simple. A single symbol expresses the end result of a long series of processes. The thing that is too complicated for the mind to grasp as a whole is the series of processes; the thing that is simple to understand and manipulate is the single symbol.

For example, the Arabic numerals, including zero, are the indispensable basis of all modern science. Imagine trying to multiply 3,142 by $5\frac{1}{2}$ per cent. in Roman numerals! Imagine a telephone directory with 1928 spelled out as MDCCCCXXVIII! Again the symbol for a definite integral, which used to strike terror to the uninitiated, is now viewed with a friendly eye, as one of the most beautiful simplifications that mathematics has ever invented. It takes artistic insight to pick out the really important concepts; and it takes artistic genius to devise a fitting notation for them. The result, when successful, is beautiful in the most satisfying sense. Beauty, I say—beauty of clearly thought-out logic, of simplicity of form—is the impelling motive and the ultimate goal of higher mathematics.

In the Chicago World's Fair, in 1933, which will exhibit in a new and striking way a century of progress in all the sciences, the old-new science of mathematics will occupy the central position. It is hoped that through that great exposition the general public, to some of whom I am now speaking, may gain a vivid picture of the beauty, as well as the utility, of the stupendous new discoveries in higher mathematics. Not every one can be a technical mathematician, just as not every one can be a technical musician; but every one can and should have some appreciation of the value of the mathematical method of thinking, just as every one can and should have an appreciation of good music. The mathematical method of thinking is the only logical method. In these days of newspaper headlines and frantic propaganda, the habit of disinterested, logical thinking is a vital necessity to all of us. What is new in mathematics is the new and growing appreciation of the fact that the study of mathematics in its eternal beauty and its ever-expanding scope is the best possible stimulus to this vital habit of disinterested, logical thinking.

PLANT HUNTING IN MADAGASCAR[1]

By Dr. CHARLES F. SWINGLE

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The desert, silent and uncompromising, lay ahead of us. Natives and whites thereabouts tersely called it "the brush." This was not a waste of drifting sand, but a tangled expanse of almost impenetrable desert growth. Many of the plants were queer and distorted, defiant of Nature's parsimonies, and resistant to them. Substantial bottle trees 10 feet thick, Euphorbias 40 feet tall, gigantic didiereas with their long leafless branches growing into the wind, wonderful aloes, kalanchoes and other flowering shrubs growing where droughts may last half a dozen years, but seemed to emphasize the uniqueness of this region. To the two botanists who paused here on the verge of this "promised land" the very grotesqueness of the plants suggested sinister allurement.

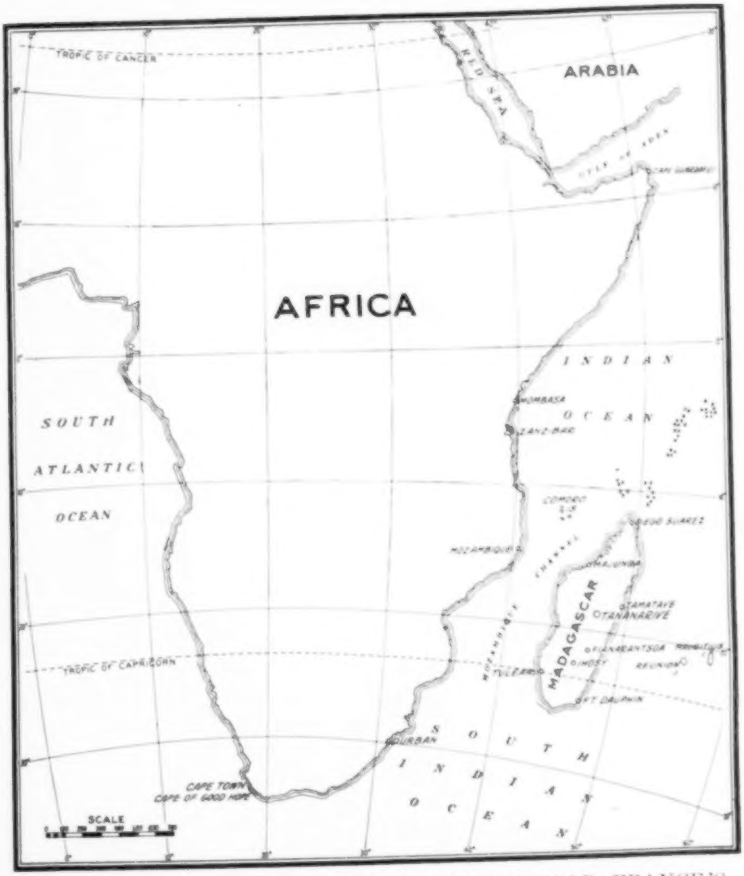
Much of southwestern Madagascar had never before been visited by plant collectors. It was my good fortune to be the first American botanist to visit any part of the island. It was rare adventure to be half a world away from home, on the trail of living plants. Especially did I hope to find *Euphorbia intisy*, an almost extinct rubber plant. Botanists best acquainted with the island feared it was gone. Even my companion, Dr. Humbert, of the University of Algiers, a veteran of two previous expeditions to Madagascar, was very dubious as to its survival. But so unique was this species, and of such promise to our arid Southwest, I could not easily relinquish hope of discovering at least a few specimens while our expedition was collecting plants in the region where intisy had formerly been so abundant.

I knew that nine tenths of all the rubber produced in the world to-day was derived from a few seeds shipped out of Brazil some 50 years ago, and that a few specimens of intisy from Madagascar might mean a real contribution to American agriculture in years to come.

It had been an arduous trip to reach the rim of the desert in the lower part of the island. Our southward journey through the interior of Madagascar is comparable in actual miles to a trip from Boston by a roundabout route to Savannah, Georgia. It had begun with an unforgetable boat ride up the Betsiboka River. We had stepped from our rickshaws at the dock in Majunga, on the northwest coast, that July morning to see a hustling gesturing crowd ready to embark with us. Our zest for the river trip departed with the first glimpse of the *Lazzarri*, a frail craft not more than 35 feet long. At least forty men and women of all colors and ages were ready to accompany us in this miniature wood-burning steamer on a treacherous inland river! We had a Malagash crew—a pilot, a fireman, a cook-waiter-barman, and a captain. From the suspiciously light color of the latter, and from his swagger and pomp, one could not but surmise that in this captain's veins was flowing the blood of old American sailors— either of the *slavers*, or the later and more numerous *whalers* who came from New England to this far-away coast.

Getting aboard the *Lazzarri* was a serious affair. Hoisted to the iron deck from the shoulders of a native who had

[1] With photographs by the author and Professor Henri Humbert.

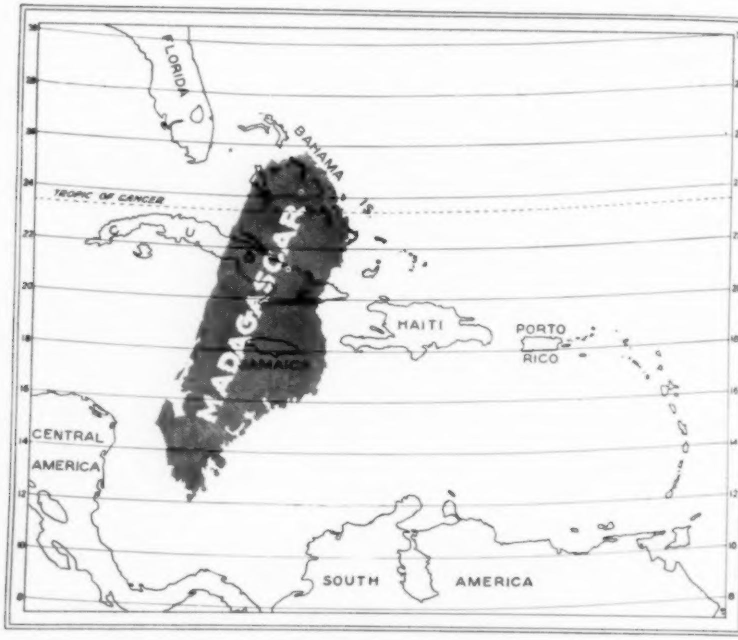


MAP SHOWING THE LOCATION OF MADAGASCAR, FRANCE'S "GREAT AFRICAN ISLAND"

ALTHOUGH MADAGASCAR LIES BUT 240 MILES OFF THE EAST COAST OF AFRICA, IT HAS DERIVED MOST OF ITS HUMAN INHABITANTS, AS WELL AS A LARGE PROPORTION OF ITS ANIMAL AND PLANT LIFE, FROM THE EAST INDIES, MORE THAN 3,000 MILES DISTANT.

waded out bearing me on his back, I called attention to my arrival by sprawling upon the muddy floor. Not only once did American dignity lie its length, measured on the slippery deck, but three times, before I could lurch to a camp chair to regain my breath and poise.

At first the discomfort of being cramped and crowded was somewhat mollified by my interest in the new country. The brick-red waters of the Betsiboka contrasted strangely with the cool green of the mangrove which lined its banks. Gradually mangrove gave way to spreading palms. These beauties of the tropics laid their dark fans against the sky in a series of unforgetable twilight pictures as we slipped by island after island. Gorgeously colored birds flitted in and out among them. Madagascar is within easy flying distance of the African coast and its bird life is largely, though by no means entirely, that of the great continent nearby. Brilliant parrakeets, snowy aigrets, and queer ibis—the bird depicted by the



NOT SUCH A LITTLE ISLAND AFTER ALL

MADAGASCAR IS APPROXIMATELY THREE TIMES AS LARGE AS ALL THE WEST INDIES COMBINED, AND STRETCHES FROM 12° TO 25.5° LATITUDE (SOUTH).

ancient Egyptians in their hieroglyphics—darted here and there.

Just before dusk our boat drew alongside the shore, and although there was no indication of a village there, thirty additional passengers appeared from somewhere and squeezed aboard. Up to this time the boat was overcrowded; after this it was almost unendurable. Certain it is, in no other country of which I know, would such jamming have been accepted so good naturedly. It was only the extreme affability of the Malagash which made this really dangerous doubling of our human cargo possible.

Early in my observation of the natives I had been impressed by their easygoing, carefree ways. At a stop on one of the Comoro Islands, since our boat was unable to approach the shore closely the town had taken to boats and come out to greet us, jabbering of pineapples, coconuts, sugar cane, and bananas for sale. In the confusion, two port police were accidentally shoved overboard into the sea! Nothing more than heated words ensued, which in the end gave way to hearty peals of laughter. Where else, but in nonchalant Madagascar, could the dignity of the law have been spilled into the brine, without vengeful consequences?

Bedtime preparations on the boat were simple. From the depths of the boat was dug up a dirty mattress. The dining table was covered with it, a sheet spread, and the most distinguished member of the passenger list—an important colonial official—escorted to it. Dr. Humbert accepted similar accommodations on one of the two benches, but I declined the other bench as graciously as possible thinking a night on my camp chair preferable. Almost immediately, however, I heard the buzz of mosquitoes

These called for prompt work. I could not afford to neglect their warning, for it was in this region that thousands of French soldiers had died of malaria during the French conquest of the island about 30 years before. One of Madagascar's early kings had bragged that he had a commander, General Tazo (fever), who could never be defeated. As yet he never has been, so I made for my mosquito net.

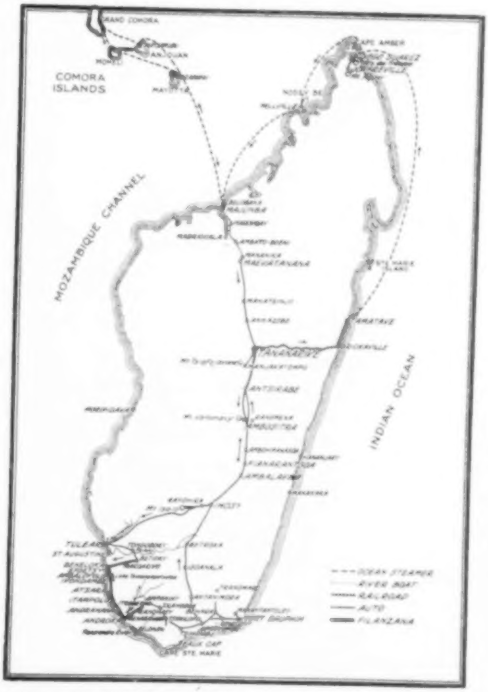
A net made to fit a cot does not fit a chair, so I dragged my own folding cot from underneath the ship's luggage, and looked around to find a spot to set it up. It was necessary to capture a few second-class brown babies and restore them to their mothers, and to ask that outstretched feet be withdrawn over the imaginary line which marked the second class from the first, in order to spread the cot. The deck was so uneven that only the middle pair of legs touched, and I teetered ingloriously the entire night. Every one who squeezed past my bed dislocated the netting and I was constantly having to adjust it. Of the many nights in Madagascar, this one made the most definite impression, probably because sleep robbed me of so few of its delights.

In the morning I looked out upon a tired, ravished country. Flat shore lines stretched back from either side, barren hills in the distance. I could scarcely believe that these river banks not so long ago were covered with dense virgin forests which had been despoiled by hand-set fires. I saw these fires being lit, and at one time could see smoke from eight separate conflagrations.

The easiest way to prepare for the cultivation of rice—the principal article of food in Madagascar—is to burn off the ground, and the natives never choose arduous labor. Surely there could be no better object lesson in conservation than these bleak hills on which only a few curious fire-resisting trees scraggled. Swarms of termites are the clean-up squad in this devastation of the forests. They build huge mounds, about the size of haycocks, and strangely, these mounds are distributed with almost geometric precision over the ground so that the landscape reminds one exactly of a field of hay ready to be hauled to the barn.

The smoke that we saw hanging on the horizon in every direction warned us that each day our expedition was delayed meant fewer plants for us to find. We knew that many plants formerly characteristic of Madagascar had already become completely exterminated, and I could only hope that intisy was not among them.

We were glad when we were per-



THE AUTHOR'S ROUTE, AND MEANS OF TRANSPORTATION EMPLOYED IN MADAGASCAR

THE RELATIVELY UNKNOWN SOUTHWESTERN PART OF THE ISLAND WAS THE PRINCIPAL OBJECTIVE OF THE EXPEDITION.

MANY AN AMERICAN ICE-CREAM CONE HAS BEEN FLAVORED BY VANILLA WHICH GREW NEAR DZAOUDZI, COMORO ISLANDS

MOST OF THE WORLD'S SUPPLY OF VANILLA COMES FROM "MADAGASCAR AND DEPENDENCIES," THE LATTER BEING THE ISLANDS OF NOSSY-BE AND STE. MARIE, AND THE COMORO ISLANDS. THE HILL TO THE LEFT IS ONE RIM OF AN EXTINCT VOLCANO, ALL THE COMOROS BEING OF VOLCANIC ORIGIN.

mitted to unload at a Sakalava village for a few hours before resuming our river trip. We were in the most torrid section of the island, and the surroundings were typical of native life. On the dusty road to the settlement oxcarts creaked along, brown men in loin cloths beside them, loaded with bales of raphia on their way to the landing place. Raphia, which comes from the young leaves of a palm, was interesting to me because I had used it many times for tying plants in greenhouses and nurseries in America.

The bare little village lay along shaggy streets, squat and brown, looking as if its unburned brick huts had been tanned by the same fierce sun

"A TANGLED EXPANSE OF ALMOST IMPENETRABLE DESERT GROWTH"

A MARVELOUS ALOE WASTES ITS FRAGRANCE ON THE DESERT AIR.

which had browned the natives who moved with careless grace in and out of them.

Native homes in Madagascar are windowless, chimneyless dwellings, their walls smoked from open fires. In the northern part of the island, they are constructed mostly of unburned brick, in the southern quarter, of woven grass or bamboo.

Storekeeping in all villages is done by the Hindoo and Chinese merchants. Curiously, a "Chinese store" is always a grocery, carrying French supplies, and a "Hindoo store" handles little except cloth. The good-natured and quite intelligent Malagash natives are childish when it comes to business dealings and are easily outwitted by the Hindoos and Chinese with whom they deal. Business is largely done by barter, for there is very little actual money in Madagascar, in spite of the richness of the island. If so small a sum as 10 francs (40 cents) is offered a native—and this represents a major purchase—almost invariably he will be unable to change it.

Goods including groceries, when not carried loose in baskets, are usually wrapped in discarded French newspapers, brought to the island expressly for this purpose, a paper bag being a rare thing. In fact, a container of any sort is something to be prized and one of the busiest spots in the market is the corner which handles discarded empty bottles, tin cans and boxes. An acquaintance I made, a French storekeeper, told me he handled an acknowledgedly inferior brand of bottled soda pop because the natives particularly liked the large false-bottom bottles it came in. We never threw away even so much as a match box or a tin foil wrapper without some native making a dash for it.

THE AUTHOR FINDS MANY INTERESTING PLANTS IN CENTRAL MADAGASCAR

Again on the river, this time jammed into two small motor boats, we found ourselves rocking along through water alive with crocodiles. The day before we had passed the village of Marovoay, meaning "many crocodiles" and not extravagantly named, for we saw hundreds of these ugly fellows, stretched out in the sun asleep on the river banks. Out of the water, these vicious fellows

"THE VERY GROTESQUENESS OF THE PLANTS SUGGESTED A SINISTER ALLUREMENT"

DR. HUMBERT STANDING BESIDE SOME OF THE DIDIEREAS.

are ignominious cowards, and at the first distant sound of our motor, they slid quickly into the water. Once in their own element, they lurked about hungrily, at a short distance. We would catch glimpses of wicked looking eyes protruding above the surface of the water, the rest of the head completely submerged. But if we were able to startle the crocodiles on the bank with a rifle shot, they, instead of gliding quietly into the water, sprang into it in

FIRES DON'T DISCOURAGE THESE

THE SCLEROCARYA AND THE MEDEMIA PALM ARE ABLE TO RESIST THE EVER-RECURRING GRASS FIRES OF THIS REGION. HAND-SET FIRES ARE ONE OF THE COMMONEST SIGHTS OF MADAGASCAR.

terror, and sank to the bottom of the stream where they crawled, completely defeated, their path indicated by bubbles on the surface.

It is an inviolate rule in Madagascar that one must never put hand or foot in water in which he can not see the bottom. Whenever one must wade in a stream, the natives beat and whip up the water with great force and shouting to frighten lurking monsters. One form of the old Madagascar trial by ordeal was to throw the suspected culprit into a crocodile-infested stream. If guilty, that was the end of him, if innocent, he made it across to the other shore.

Natives seldom molest these dangerous creatures. It is not fear alone, but religious tabus which protect the crocodile and other reptiles in Madagascar. The native is willing to risk the crocodile's jaws, but dares not offend the crocodile's soul!

We had several hunters aboard, and with characteristic indifference to time or schedules, the boat veered and detoured constantly to give them opportunity to bag their game successfully. We found here, as everywhere, only astonishment or languid indifference to greet our ambitious planning for a speedy trip. It was as if a people existed who felt absolutely no resentment against the shortness of life and breath.

We felt as though we had gone through a modern trial by ordeal before the required three days of river travel were behind us and we struck the automobile road to the capital, Tananarive.

Excellent new roads built by crude hand labor seem unusual in a country with so few cars to use them. Any motor vehicle was always a source of wonderment and almost fear to the Malagash natives. An automobile does not pass over this road every day, yet mile on mile of fine smooth highway stretches through the heart of the country and these roads are being continually extended.

ONCE SUPERB TROPICAL FOREST, NOW BARREN PRAIRIE COVERED WITH TERMITE NESTS

Our trip from the coast to Tananarive, only 250 miles on the map, had taken us six days, or virtually the same time as was required for this trip 50 years ago. It is certain that within a few months the highway will be completed

OXCARTS HELP, BUT DO NOT REPLACE THE HUMAN BACK IN MADAGASCAR

all the way, and buses will make the entire trip, eliminating the boats altogether. When this occurs, it will mean the passing of one of the most appallingly picturesque journeys of old Madagascar.

Our week in the capital city was one of constant planning for the days ahead. We must guard against accident to our precious collections which were already growing. We must take care lest some unforseen detail at Tulear would defeat us at the last in our determination to explore the southernmost area. Each of us must take on some twenty porters to transport us and our equipment into the desert—would we be able to find men willing to risk their lives with us? Always in my mind was anxiety lest I should find *Euphorbia intisy* already added to the long list of non-existent plants.

During our months of travel on the island we had only a few hours by rail, and were dependent on public bus or private cars the rest of the way. We slept in huts by the road, empty windowless houses, especially reserved for European travelers, and seldom occupied so they were free from filth and vermin. The roads in the southern half of Madagascar are strictly dry-weather conveniences, as there are no bridges, and when streams are high, they are impassable. Ferries are made by joining three or four tiny dugout canoes together, and laying a few boards across. They are made chiefly to accommodate foot passengers and on rare occasions automobiles.

It looked as if our expedition might come to an unceremonious end at one such crossing near Tulear. We arrived after dark at the water's edge with our truck heavily loaded with all of the equipment for the desert journey. We well knew the custom that no one on the island, regardless of the need, ever labors after the setting of the sun; but to spend the night here meant unloading the truck which had taken hours to pack. We were immediately refused when we asked the natives to help us across. It was dark, they told us, the river was high, and what was final, the ferry was broken. We pled and argued.

and, finally, when we offered liberal tips, help became plentiful, the river negotiable, and the ferry ready to go.

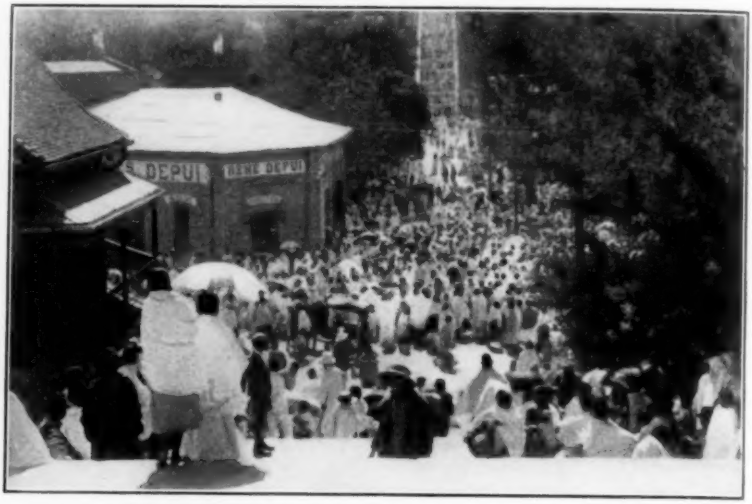
It was a perilous undertaking. With the small canoes together, and planked, we found we had only four inches to spare at either end of the raft. It required eight men to hold it to keep it from skidding out from under as we manouvered the truck into position and blocked its wheels in place. The river was swift and deep and teeming with crocodiles. Our overloaded truck forced the ferry almost level with the water. The crossing was effected by a sort of an endless rope arrangement with the ferry fastened to the rope. Two natives slowly pulled the boat across with our most fervent good wishes and prayers to assist them. Once over, it was a long task to build a trustworthy landing on the bank. When we were safely on solid ground again, my traveling companion, who could speak little English, and I, who could speak little French, congratulated each other, and each of us understood perfectly.

At Tulear, good luck was with us and French authority was brought to bear on the natives we needed for carriers. They were simply drafted into our service from several villages and gathered at Betioky where we were to start into to brush. Much as we needed them we could not but sympathize heartily with their protests against such an excursion. It was the first instance we saw of any sullenness among the Malagash, and it was undoubtedly justified as events later proved.

These Malagash people are not, as one would suppose, black men like their African neighbors only 240 miles away. Strange to say, they have practically the same language and similar appearance as the Sumatrans, with 3,000 miles of ocean between them. They are erect, straight haired, brown Melayo-Melane-

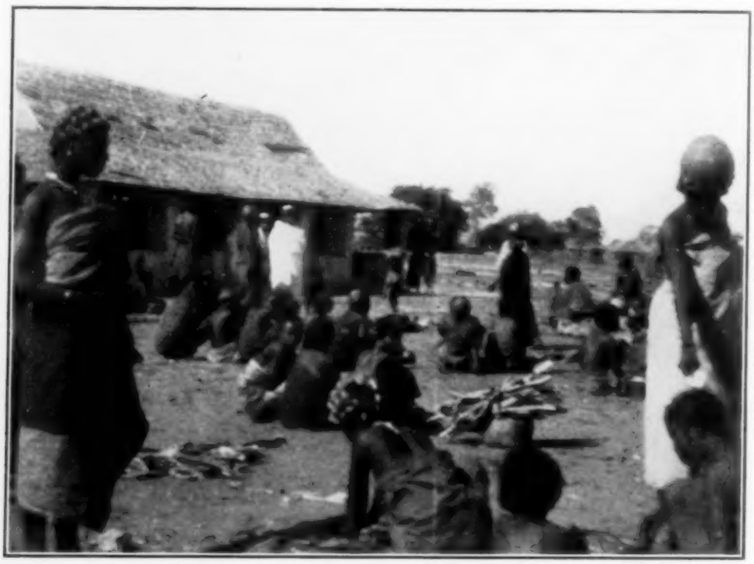
DRIED GRASSHOPPERS OCCUPY A PROMINENT PART OF THE MARKET IN MADAGASCAR

FOR ONLY A SOU (ONE-FIFTH OF A CENT) ONE CAN PURCHASE A WHOLE PILE OF THESE TASTY CREATURES. OTHER PEOPLES MAY LOOK UPON GRASSHOPPERS AS A CRUEL VISITATION OF PROVIDENCE. NOT SO THE MALAGASH; TO THEM IT MEANS A PERIOD OF FEASTING, FOR GRASSHOPPERS ARE A CHOICE VIAND ON THE ISLAND.



NOT A KU KLUX GATHERING BUT A CORNER OF THE *ZOMA* AT TANANARIVE ON MARKET DAY

sians. In the south of the island they are frequently dressed only in their loin cloths, the men carrying spears as the sign of gentlemen. In the more populated northern sections the people are clothed in ridiculous second-hand European garments shipped there for sale, with their native *lambas* (shawls) wrapped over all. I was quite startled one day to observe a dusky grinning



EVERY DAY IS MARKET DAY AT AMPANIHY

NOTE THE PREVALENCE OF "SUNTAN BACKS" AND THE GENEROUS USE OF TALLOW IN ARRANGING MILADY'S COIFFURE.

Malagash lad wearing a hat on which was displayed the proud name of Rugby!

A gathering of Malagash natives reminded me of "roughneck" day, years before, on my college campus, when all students gleefully dressed themselves in the most incongruous apparel they could assemble to celebrate the Ides of March. Top hats and bare shins, dress coats over night shirts, and Spanish combs in unruly locks—fashion's mandates are elastic in Madagascar.

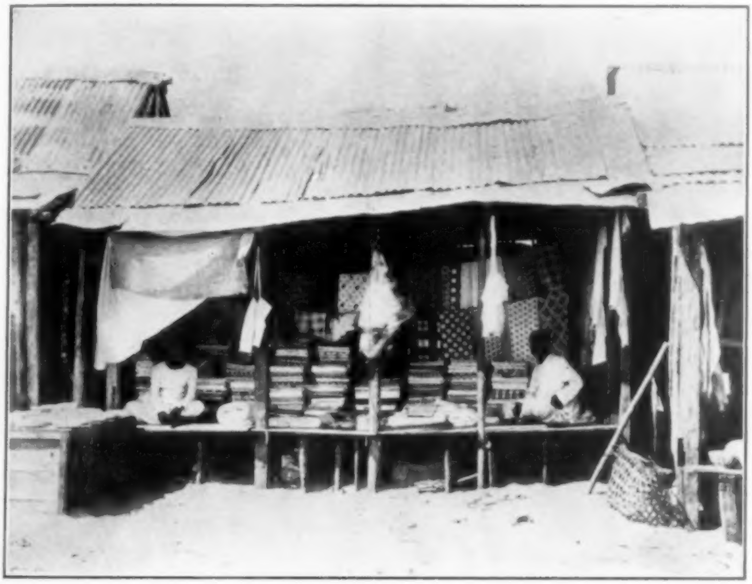
They are a patient, happy race, naïve in their ideas of morality, to be sure, but a decent, likable lot.

We had two chauffeurs on part of our journey who, when they presented themselves, told us they were brothers.

"But how is it," I inquired, "that you two, who are brothers, look so unlike?"

They replied: "With you, we are told, whole families often have the same father. To us, this seems very hard to understand."

The one evidence of earthly ambition on the part of the natives is their passion for acquiring herds of zebu cattle. The size of their flocks is their one measure of worldly standing. These cattle are never fed, are seldom driven to water, and are rarely milked or killed for food.



Photograph by Dick Delonlay.

MADAGASCAR HAS MANY CLOTHING STORES SUCH AS THIS, BUT FEW GROCERY STORES

THIS IS A TYPICAL "HINDOO SHOP," WHILE MOST OF THE GROCERY STORES, FOR EQUALLY OBVIOUS REASONS, ARE KNOWN AS "CHINESE SHOPS."

The incident was told me of a prosperous Malagash native whose wife and very young infant were suffering from cold, being destitute of clothing. He was brought before a colonial official and rebuked for allowing his wife to die of neglect while he was rich in cattle.

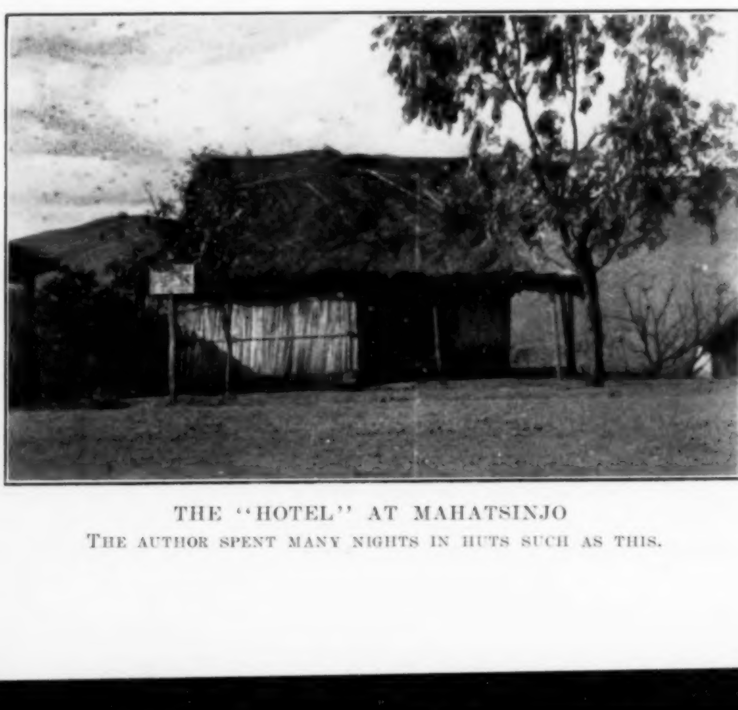
"But if I part with a zebu," he replied, "It is so very hard to get another."

At Betioky, we were to lose all communication with civilization for a time.

FRAIL GRASS HUTS ARE THE RULE IN SOUTHERN MADAGASCAR

Mail communication was almost a negligible factor with us at any time, as it requires many weeks to send letters across the island, a very excellent and cheap telegraph system being universally depended upon. Courier service is sometimes used for short-distance mail service between officials or Europeans quite generally, and was amusing to us. A note is given to the native carrier who places it in the end of a split stick, and as he runs with it to its destination he offers it to every European he meets. The message usually reaches the intended person eventually, though I would not recommend sending secret information by this means.

Under a cloudless sky, our filanzana



THE "HOTEL" AT MAHATSINJO

THE AUTHOR SPENT MANY NIGHTS IN HUTS SUCH AS THIS.

expedition set out into the desert. During half of each year there is absolutely no rainfall here and drouths lasting as long as six years have been known.

Thrilling stories had drifted out of the brush, and others will never be known. We knew the authentic story of Dr. Brown, the young Carnegie surveyor, whose trail we were partially to follow. He was proceeding as we were, by filanzana, and was several days out when his water supply was exhausted. Even his porters had refused the only moisture to be had, foul mud at the bottom of a water hole. It seemed that but one fate awaited the party, several days away from water in any direction, under a fierce tropical sun. But in the night, miraculously, for it was the first time in three years, a shower fell. The porters rushed to spread their lambas to catch the precious drops—lambas which probably had not been washed since the last rain—and obtained drinking water by wringing them out into their calabash vessels.

Small wonder that our porters grumbled over a similar excursion!

That plant life should be so abundant in this rainless country seems almost incredible. It is made possible only by the very great humidity at night. Dense dews and fogs occur almost nightly. The dew on a large plant becomes so heavy during the night that it often runs down about the base, and in the morning the ground about the plant looks as if it had been wet by a shower. The desert plants have developed water-utilizing devices of various queer sorts which render them resistant to the unusual drouth conditions.

Minutes in the morning on the desert are precious, so Dr. Humbert and I brewed a hasty cup of cocoa at dawn each day, and with little more for

Photograph by Dick Delonlay.

DWELLINGS OF UNBURNED BRICK PREDOMINATE IN CENTRAL AND NORTHERN MADAGASCAR

NOTE THAT THE HOUSES ARE WITHOUT CHIMNEYS.

Photograph by Robert Taylor.

WOOD CARVING IS ALSO A FAVORITE PASTIME FOR MANY OF THE MALAGASH

breakfast, climbed into our filanzanas—swinging chairs borne by two long horizontal poles. The natives did not breakfast at all until late in the morning, and sometimes they had their first meal long after noon.

The dismal chill of the early hours was as difficult to withstand as the heat later on. I began the day wearing a khaki shirt, a sweater, a coat, and a light overcoat, but even so I was never quite warm enough for comfort.

Four natives picked up each of our two curious filanzana chairs and jogged off. One porter could work only about five minutes without needing relief, then he would manipulate a shift with his alternate. Every step of the porters is a jar to the passenger, and each shift a real jolt. No two of the porters were the same height, and the bobbing about was indescribably fatiguing. The first morning while I was attempting to adjust myself to the discomfort a porter stumbled while making the shift, and I was dumped out into the path.

The porters were an irresponsible, joking group, talkative to the point of irritation at times. My filanzana was decorated with the personal belongings of my men—foot shields cut from goat skins, charms, souvenirs, spoons for their rice, and even tiny woven mats for their beds. We had to threaten to strap the two camera porters to the filanzana also, as they were constantly wandering ahead or lagging behind when we needed the camera. Moreover, although the

water supply was all important, we had to watch the natives every morning to see that each filled his individual calabash, for during the day the large water bags were with the baggage carriers who might be miles ahead of our more leisurely group.

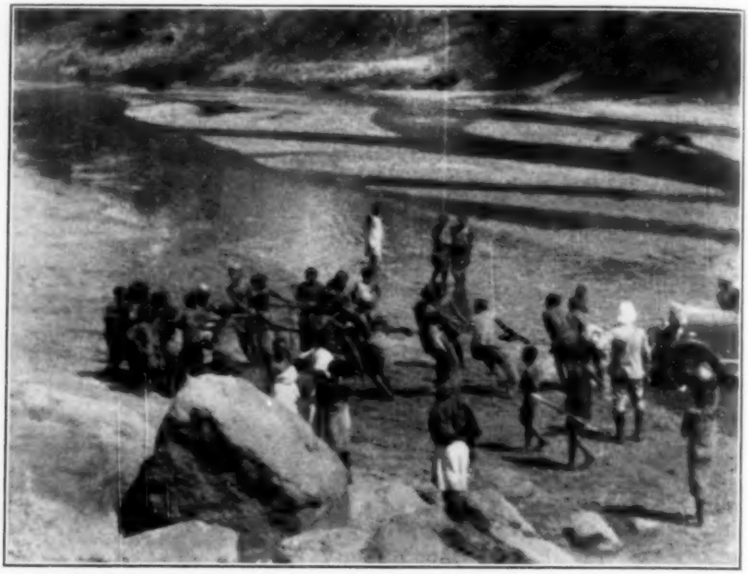
Our experience differed from that of the average plant collector, in that we seldom had to reconnoiter for specimens, as the place was untouched by botanists and we were surrounded by plant life as we followed the trail. It was rest from our uncomfortable riding to get down and gather plants, and at intervals we would walk for periods of half an hour or so to rest the porters. An hour's walk is a very long one for a white man in any part of Madagascar, and is only rarely made by a European. Automobiles being scarce, white men use, whenever the road permits, rickshaws pulled and shoved by "*pousse-pousse*" boys. Of course we had no such de luxe service in the brush.

About eleven o'clock the desert heat was upon us in its full intensity, and we made our long stop. How the natives could endure this tropical sun with no protective head covering is a source of wonder. It is considered by those who know the climate best to be positively dangerous to go without a helmet for even five minutes. White men's helmets do not come off outdoors, even in the shade. The blinding glare of the desert sun would have been almost unendurable had it not been for occasional tall, spreading tamarind trees, which afforded the only real shade in the desert. We always made our stop under one if possible.

The porters cooked their main meal at this time. Sometimes it consisted of manioc or of sweet potatoes, but the usual meal was of rice. Each man had the unbelievable allotment of more than two pounds of dry rice a day which he actually consumed, sometimes at one meal. It was really well cooked, each grain flaky and whole, though unsalted. It was boiled exactly twenty-five min-

Photograph by Dick Delonlay.

HOVA WOMAN WEAVING A SILK LAMBA ON A NATIVE LOOM



TRAVELING BY AUTO IN MADAGASCAR IS NOT AS SIMPLE AS IT SOUNDS

FORTUNATELY MEN AND WOMEN OF THE VILLAGES WERE ALWAYS WILLING TO TURN OUT AND LEND A HAND.

utes, and so exact are they in this that they are accustomed to measure time by the length of their rice cooking.

Occasionally we purchased a desert-herded animal to slaughter for meat. But supplying the group with meat was complicated, because of the tabus certain tribes held against certain meats. Our men were of several tribes and broke up into tribal groups for their eating. Some could not eat beef, some could not eat mutton or goat meat. They were quiet about these idiosyncrasies, and often we did not know of their shortage of food until they felt it on the march. We always carried a few live chickens with us, and these were an unmixed blessing to Dr. Humbert and me, who had to prepare our own meals. We could not obtain a cook (this sounds like civilization), and consequently depended on our own culinary efforts, with but slight help from the native soldier in our party who sometimes tried to aid at mealtime.

The porters sometimes took advantage of the strong light at noon to dig out chiggers from their feet. The feet of all were badly mutilated with gouging out these pests. Chigger hunting is a very necessary rite in all parts of the island as this tiny mite is a very serious scourge. During my three and one-half months in Madagascar my unshod feet never touched the floor or ground for danger of picking up one of these tiny mites. They are extremely minute, so small that I never managed to spy one, although I saw natives everywhere searching them out. They burrow under the nails or under the thick callouses on the soles of the feet, lay their eggs and incubate them. The ensuing poisoning is very serious and sometimes fatal. Native girls of keen eyesight find chigger hunting a paying occupation. Often they find the chigger buried a quarter of an inch. It is not an outdoor mite, but one that infests only buildings, hiding in crevices and corners.

Occasionally, during our stops there were complications with our porters which we must straighten out. Leprosy is very common on the island, and we saw many persons whom we had cause to suspect. At one village, isolated to the outskirts, we came upon a leper, a woman so ravished by the disease that she appeared aged and revolting. The porters began chatting with her in their customary easygoing way, and were not the least bit fearful. We were concerned over the situation. We finally gave the chief of the village a few francs, asking him to give them to the creature, with instructions that she keep away from our men. We were somewhat taken aback to find that, having opulence thus thrust upon her, the woman immediately began buying trinkets from our porters, and a merry exchange of goods was going on before we could put a stop to it.

We always took advantage of the noon-day sun to assist us in drying such of our specimens as we wished to preserve in the dry state. Dr. Humbert was especially responsible for gathering and classifying these dry herbarium specimens, while I had been sent particularly to bring back living plants. No collection in America had a display of Madagascar plants, either living or dead, and it was to remedy this lack that our expedition had been organized by the Arnold Arboretum of Harvard University, and the United States Department of Agriculture, in conjunction with the University of Algiers.

These desert plants, because of their ability to store and utilize water in their leaves, stems and roots, were very difficult to dry between blotters as is the usual process, and our problem was to speed up the drying, avoiding rain and dew, and using every minute of sunshine we could. The plants we gathered as we marched, and carefully placed

IT ISN'T EVERY YEAR THAT THEY HAVE A CHANCE TO OBSERVE A WHITE VISITOR

CURIOUS NATIVES ALWAYS GATHER AT THE "CASE PASSAGE" OR TRAVELER'S HUT WHICH IS PROVIDED IN EVERY REMOTE SECTION OF MADAGASCAR FOR THE USE OF EUROPEAN VISITORS.

MEAL TIME

HATS MAKE FINE PLATES FOR SERVING RICE.

them into baskets. Each plant had to be removed from the ground in as nearly a perfect state as possible. We did not trust our porters to do this particular work. Always must we find plants that were in bloom, for of course to be of much use as herbarium specimens, they must have a good, open blossom. Whenever we could find them, we dug up twenty or thirty of each kind, carefully tying them together.

Within a few minutes after making our noon-day stop our camp would take on a queer cluttered appearance as we untied bulky bundles of blotters and laid them out in little piles in the sun to dry, carefully weighting them down with sticks and stones to keep them from blowing. Many of the recently gathered plants had to be cut into several pieces to be accommodated, for blossoms, stems, roots and all must be placed between special absorbent sheets of paper. With few exceptions, our plants were never pressed as one might suppose; no pressure was brought to bear on any of them except that caused by the straps used to bundle the unwieldy layers of blotters together. We carried a queer collection of jars and bottles and preserving solutions for fleshy forms impossible to dry.

Occasionally on coming to a village, we found it necessary to stop and dry out plants and blotters with artificial heat. We would construct racks 15 or 20 feet long, 3 feet off the ground, out of small tree trunks, laying out our piles of blotters on them. Underneath we would build a slow, smoldering line of fire which had to be kept burning steadily but not blazing.

While we did our clerical work, or ironed other plants with a sad-iron to dry them, we had a native tend this fire. On one stop we employed a boy for this work, but we were continually irritated to step from the house in which we were working to find him gone. Finally I decided to accomplish our ends by gentle means, so I bought him a nickel's worth of bananas—an enormous number for one boy—and two cents' worth of peanuts. Capturing him down the street

I escorted him back to our camp and urged him to make himself contented by the fire with food and reverie. Returning an hour later I found the fire out, the fifteen or twenty bananas gone, the peanuts consumed, and the boy stretched out in the sun, sleeping peacefully.

Properly dried herbarium specimens will last in usable condition for centuries. Botanists to-day are using some prepared by Linnaeus, "the father of botany," two hundred years ago. But improperly cared-for specimens mold and are ruined within a few days. The reader can conceive of the labor connected with such an enterprise as ours, when he knows that besides the living plant material we brought back some 3,000 herbarium numbers, each number representing five to thirty plants in flower, each specimen having gone through a drying process of from several days to several weeks. We must always know the exact locality in which we collected each plant, and the date, and our best tentative field classification needed to be made in every case.

Afternoon on the desert was a repetition of the morning, and our two filanzanas often traveled several miles apart as each of us paused and gathered material. Evening camp was made early to enable us to care for the day's accumulation of plants.

Many a night after a strenuous day of collecting I worked until one or two in the morning caring for my living plants, with a sunrise start to make next day. These could not accumulate as the dry specimens might if necessary. The living plant material must be wrapped in paper in small bundles, keeping varieties and lots separate, and packed in tin cracker boxes. When I landed in Madagascar, short of packing material for my plants, I bought a few cents' worth of coconut husks—the thick fibrous covering which grows around the coconut—and five or six men spent the day shredding this for me, to the great amusement of the other natives. I also used the

ACROSS THE MAHAFALY PLATEAU

THE EXPEDITION ON THE MARCH.

THE AUTHOR IN HIS MADAGASCAR PRAIRIE SCHOONER

FILANZANA TRAVEL HAS LITTLE TO OFFER IN THE WAY OF COMFORT OR SPEED.

roots of ferns which grow on the trunks of trees, as a satisfactory makeshift for really desirable moss, of which I found but little in Madagascar. My entire collection of plants had to be gone over thoroughly very often, rewrapping and discarding where necessary. Naturally, seeds are by far the easiest of living plant material to handle, and these I obtained whenever possible.

With nightfall the clammy desert chill sent us to our wraps and blankets, but the natives lay on the bare ground around the ashes of their fires, with only their thin lambas for protection from the cold.

The responsibility for the lives of our forty men in a country where water was so difficult to obtain was no slight one. They had been forced to accompany us and I felt real concern for their safety as well as for our own. We had started with all the water it was possible for us to carry, but it was necessary for us to plan to fill our water bags at village waterholes along the way.

It looked as if the porters' fears were to be swiftly realized, when at the end of the second day's march our water supply ran out. We had found that the two or three tiny villages we passed had not enough water for their own needs, and drinking water and water for cooking rice for our large party was simply unobtainable. Our only hope was to push ahead the third day, as quickly as possible, trusting to find a sufficient supply before it was too late.

Our physical suffering and our torturing thoughts that day, struggling under a merciless sun, are indescribable. An ominous hush fell over the party. It was not broken when, one after another, five of our faithful porters collapsed by the roadside. We paused only to moisten the lips of the first two with the last hoarded drops of water—we could do nothing for the other three. We marched on silently in the desperate hope that we might return to them before it was too late. Of course we could no longer depend on filanzana travel and in spite of our exhaustion we must take up the uncertain journey on foot.

Toward the middle of the afternoon we sighted a village ahead, and we found to our joy enough water there so that each of our half-crazed men might have a sip.

We were too weakened to return for our fallen men, but villagers were sent to rescue them. Very fortunately, they were all resuscitated, although two were of no more assistance to us, and had not recovered fully when we parted from them at the end of the trip. Separated from others in the party which made a trip to a distant waterhole later that afternoon, I collapsed twice, and was only fortunate in recovering consciousness and strength to the point where I could resume the walk.

Our progress was much slowed down after this harrowing experience, as all of us were much affected. Moreover, during the weeks in the desert which followed, we were constantly tormented by the shortage of water, at best being forced to drink from reeking waterholes after animals had fouled them, at worst, going without. Swallowing our daily dose of quinine was truly a pleasant process, for it took away the nauseating taste of the awful water.

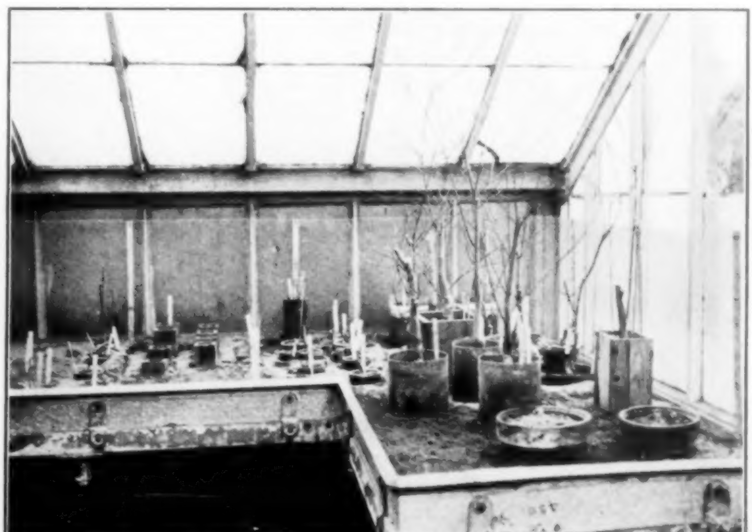
The first day out I had said to the chief of the porters, "Do you know the rubber plant called *intisy?*"

"Eka (yes)," came the answer we hardly dared expect.

"How far is it?"

"We will surely find it right on our path within a few hours," he promised. We started in great anticipation, and surely enough within a few hours he proudly pointed out his treasure. Imagine our sickening realization that it was a totally different rubber plant, of inferior quality, and one already in our collection!

We had been in the desert two weeks and as yet there had not been a trace of the plant. Members of our own party had not attempted to offer more information after the first day, but other natives, of whom we were constantly inquiring, were certain they could direct us to the plant. But their reassuring predictions, though exceedingly well



SOME OF THE ORIGINAL INTISY PLANTS, AND A FEW OF THE PROPAGATIONS, IN THE WASHINGTON GREENHOUSES

THE FIRST PLANT OF *EUPHORBIA INTISY* FOUND BY THE EXPEDITION

THIS IS "AN INCONSPICUOUS LITTLE TREE WITH LEAFLESS GREEN BRANCHES," BUT IT YIELDS ONE OF THE BEST RUBBERS KNOWN, AND FOR THIS REASON IT HAS BEEN VIRTUALLY EXTERMINATED BY THE MADAGASCAR NATIVES.

meant, served only to increase our disappointment at finding none of them to be true.

A village chief had been our latest informant and after a tedious excursion we found that his information was as useless as all the rest had been. Almost with resentment I listened to the words of cheer he poured out to us as we departed.

"I know now which one you wish, don't be sad for you will find it a few hours on."

Scarcely two hours later, as my porters jogged along, I looked up to see a slender, inconspicuous little tree with leafless green branches, growing in the brush at the side of the road. I was almost too excited to shout "Andras (stop)!" to my brown men.

I was out of the filanzana and scrambling through the brush in a minute. Once I had reached the tree I felt certain it was intisy, but I took my knife and anxiously made a slash in one of the slender stems, and watched the milk latex ooze out. Dipping my finger in this white liquid, I gleefully saw it harden into a gummy mass of almost pure rubber, and I knew that at last I had come upon my coveted *Euphorbia intisy*. No other rubber plant is known which produces a latex that hardens into such high-quality rubber entirely without artificial treatment. It is the fact that this high-quality rubber can be handled with such ease, which accounts for its exploitation by the natives. Many years ago all accessible trees had been slashed mercilessly and soon killed by their ruthless methods of rubber collecting.

"Two francs (eight cents, or a day's wages) for each plant like this you can dig up and bring us!" I told my porters, and they scattered out to find other specimens. Their enthusiasm did not last long however, when they found the little trees were in dry stony ground, and very difficult to dig without injuring the very queer roots with which they were equipped. Intisy differs from

DIGGING INTISY PLANTS OUT OF DRY, STONY SOIL WAS HARD AND UNUSUAL WORK FOR THE PORTERS

any known plant, having roots which store water in bulbous swellings which occur one after another, like link sausages.

After finding intisy, my care for my live plants was all the more vigilant. On coming to a village, my first concern was to secure tin cracker boxes which I used as containers for many plants on the entire return voyage.

I stepped into a Hindoo store at one point which carried a little candy in addition to its usual stock of cloth.

"Have you any empty tin boxes?" I asked.

The search turned up a greasy box which was offered confidently.

"No it's too dirty for me to put my plants in," I told him.

"Oh, that's all right," the obliging shopkeeper replied, dumping the contents of a half-empty candy box into the despised container. "The dirty one is quite as good to me!"

Once out of the desert, we sent the porters back on foot, by a short route, and I turned homeward with my living plants. If I had gone through every privation to obtain them, once on shipboard, I was speeded on my way with all that modern transportation could do to aid me. I was assured that no quarter on the boat was too good for my queer luggage, and every day I must open each box to air and syringe and examine my specimens. Before sailing I had picked up eight miniature greenhouses which I had taken to the island full of choice citrus plants, a gift from our government to the Madagascar government, and these were now full of island plants making the trip to America. My most troublesome piece of baggage was an enamel kettle full of plants in a liquid preservative which I carried 10,000 miles with only a leaky cover, there being no tight container obtainable in Madagascar.

In each of my twenty-three pieces of luggage I had tucked specimens of intisy, so that nothing but the sinking of the vessel would have robbed me of *all* my spoils. I am quite sure that had I gone to the bottom of the Atlantic, I would have had intisy in all my pockets!

To what extent this queer plant will permit itself to become Americanized, no one can say. The fact that specimens of intisy are now thriving in Florida and California leads us to hope that the question will not long remain unanswered.

A CINEMATOGRAPHIC STUDY OF SPRINTERS

By Professor WALLACE O. FENN

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THE earliest incentive to the development of the motion picture was the desire to study the gaits of animals and the foot movements of the race horse (Muybridge, 1873).[1] Likewise the pioneer efforts in 1885 of the French physiologist, Marey,[2] in this direction, were particularly devoted toward the study of the movements of the limbs of men in running and walking. In more than forty years which have elapsed since that time the motion picture industry has passed far beyond its original objective. Simultaneously both the science and the art of running have advanced. On the one hand the physiologist has learned much concerning muscles and muscular movements which was unknown to Marey, and on the other hand sportsmen have accumulated a greater wealth of practical experience and empirical rules which have helped to make good runners and to break many world's records.

The moving pictures have contributed something to this advance but this contribution has been chiefly to the "anatomy" of running; it has described for us the orbits of the arms and legs in good and bad runners and has defined the times of contractions and relaxation of the various muscles. The moving pictures have not told us much, however, concerning the fundamental *physiology* of sprint running. It may be of interest, therefore, to describe the results of a cinematographic study of sprinters which has thrown some light on the fundamental question, "What is the limiting factor in running?" Why can man never attain a speed greater than a mere 10.6 meter per second? Why does it become increasingly difficult to beat a world's record?

For the moving pictures used in this study[3] I am indebted to Mr. C. A. Morrison, of the Eastman Teaching Medical Films. The general appearance of the films can be seen from Fig. 1, which shows a man running behind a lattice work with squares 1 meter on a side. There were 128 exposures per second, the length of each exposure lasting about one-thousandth of a second. The man wore a white collar with a black spot on it and a little marker with another black spot tied securely around the waist. These provided fixed points for measurement in determining the forward progress of the body and its rise and fall with each step. Croquet balls are dropped along the side of the frame-work in order to measure the speed of the film. One of these can be seen falling in Fig 2. The details of the methods used for the study of the films need not concern us here. Only the general argument which led to the taking of the films and the conclusions drawn from the study will be outlined in what follows.

THE EXTERNAL RESISTANCE

The runner appears to be pushing against a negligible external resistance, the air. This air resistance has been measured on small models of men in-

[1] Muybridge, "Animal Locomotion." London, 1873.

[2] E. J. Marey, "Developpement de la méthode graphique par l'emploi de la photographie," 1885.

[3] W. O. Fenn, "Frictional and Kinetic Factors in the Work of Sprint Running," *Amer. Jour. Physiol.*, 92, 583, 1930; "Work Against Gravity and Work Due to Velocity Changes in Running," *Amer. Jour. Physiol.*, 93, 433, 1930.

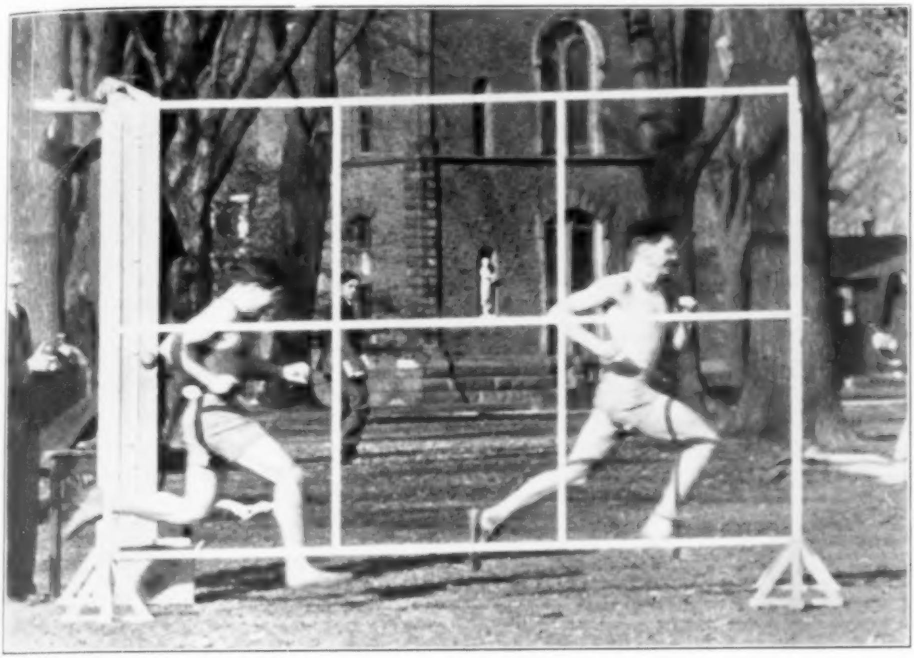

FIG. 1. SAMPLE FROM THE MOVING PICTURES USED FOR THE STUDY OF THE MECHANICS OF SPRINTING. THE SECOND RUNNER SHOWS A BLACK SPOT ATTACHED TO THE BELT BEHIND. BOTH RUNNERS HAVE BLACK SPOTS ON THE NECK BAND.

dependently by DuBois Reymond and by A. V. Hill, and the figure they obtained has been confirmed by the writer by quite a different method. Thus it has been found that for an average man running at top speed (7.5 meters per second) the air resistance is about 1.2 kgm. This is certainly a rather small resistance to be overcome by a man who at the start of a race can exert an average force more like 50 kgm. (Hill). Yet when going at maximum and hence constant speed the average propelling force must be just equal to the resisting force.

There is, however, another source of external resistance and this is the resistance offered by the ground. The foot does not strike the ground directly under the runner but somewhat in front of him. In fact a study of the moving pictures shows that the leg makes an angle with the ground at the moment of contact of 70–80 degrees instead of 90 degrees. This can be seen clearly in the second runner in Fig. 1. The result is that the runner tends to check his speed slightly each time his foot touches the ground. If one knows the location of the center of gravity of the body as well as its velocity at the moment of contact and its direction of movement then it is possible to calculate from the angle of contact how large this check on the movement of the runner is. Carrying out this relatively simple calculation it is found that the runner loses at each contact about $1\frac{1}{2}$ per cent. of his velocity. At speeds of 7.5 meters per second, which are about maximum for most untrained runners, this amounts on the average to about twice the resistance offered by the air. This resistance is overcome by the foot while it is in contact with the ground as it gives a forward push to the body.

It is theoretically possible to measure this ground resistance also by determining from the moving picture film the maximum change in velocity of the body during each step. This was in fact done, but it turned out to be much more difficult and much less accurate than had been expected. Unfortunately, the velocity of the body is, strictly, the velocity of its center of gravity, and this is by no means the same as the velocity of the nose or the hips or of any other part of the body. While the foot is on the ground the hips tend to get ahead of the nose, and while the runner is in the air the nose tends to catch up again. These changes in velocity are much greater fortunately than the changes in velocity of the center of gravity. This can clearly be shown by the laborious process of calculating from the various positions of the arms and legs at each moment in the race exactly where the center of gravity is. This calculation may be avoided by the use of the strange mechanical model illustrated in Fig. 2. This model was designed by O. Fischer.[4] It utilizes a series of interconnected pantographs each one of which has its terminals connected to the centers of gravities of two adjoining parts of the body and by its central point indicates the common center of gravity of these two parts irrespective of any change in their relative positions. Thus two pantographs on each leg indicate its common center of gravity ($S_{3, 5, 7}$) in whatever ways the knee and ankle may be bent. The common center of gravity of both legs (S_{gb167}) is indicated by another pantograph connecting the centers of gravity of the two legs separately. Still another pantograph indicates the combined center of gravity of the two legs and the body, and so on. Finally the point

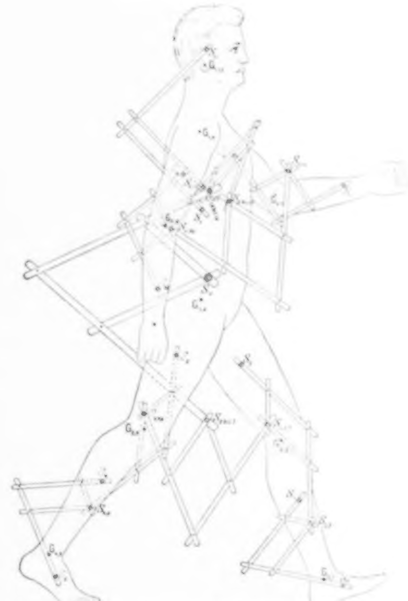

FIG. 2. THE POINT S_0 IN THIS SERIES OF PANTOGRAPHS INDICATES THE MOVEMENTS OF THE CENTER OF GRAVITY OF THE WHOLE BODY AS THE MAN WALKS. THE POINTS S_1, S_2, ETC., INDICATE THE FIXED POSITIONS OF THE CENTERS OF GRAVITY OF THE SEPARATE PARTS OF THE BODY. APPARATUS OF O. FISCHER.

S_0 (Fig. 2) indicates the center of gravity of the whole body for any position of the arms or legs. Even this method of following the center of gravity of the body is laborious enough and in any case the error is so large that the results are of no value for this purpose.

The most accurate and the most elegant method of measuring the ground resistance is to construct a small movable platform which is incorporated into a running track (Fig. 3). The runner arranges to step on this platform as he runs. The platform is mounted on wheels and moves very slightly backwards and forwards against strong springs and records its horizontal movements by a lever writing on a moving drum beside the running track. Thus it is possible to

[4] This model is reproduced in "Mechanik der Gelenke," by R. Fick, Vol. II, page 345, 1910. It is actually manufactured by E. Zimmermann, Berlin.

measure exactly what forces are exerted horizontally against the ground both when the foot strikes the ground and when it leaves it. In this way it is found that the total average external resistance (ground resistance plus air resistance) is about 5 kgm. for a man running at 7.5 meters per second and requires half a horse power of energy expenditure to overcome it (air resistance 0.16 horse power, ground resistance about twice as great, 0.34 horse power). This method gives a result therefore which agrees with the more approximate estimate reached from a study of the moving pictures.

Incidentally it may be added that the mean difference between the forward pressure recorded when the foot strikes the platform and the backward pressure recorded when it leaves provides a measure of the air resistance to motion 1.6 kgm. which agrees well with the figure 1.2 kgm. obtained on miniature men by Du Bois Reymond as described above.

The Total Horse Power Available for a Sprint

We learn from these observations that energy must be expended in a race at the rate of half a horse power in order to overcome the external resistance. It becomes of interest and importance therefore to inquire what the total horse power expended by the man is. This can be determined in the following manner. For a sprint of a given distance a man consumes a certain extra amount of oxygen every liter of which is equivalent to 5 large calories of energy. For a sprint lasting 10 seconds we may say that he consumes one tenth of this total excess oxygen per second. More or less arbitrary but unimportant corrections should be made to allow for the energy expended in bringing the body to maximum speed and in slowing it up again at the end of the end of the race.[5] The final result gives us the rate of energy expenditure or the total horse power developed in running at top speed. In carrying out this measurement the basal rate of oxygen consumption is first determined. Then at a given signal the runner holds his breath and sprints down a long corridor. He makes his next expiration into a rubber bag or spirometer at the end of the corridor so that all his expired air for the next half hour or more can be collected and analyzed. The results which we have obtained in this way on 19 different runners give an average figure of 13.2 horse power. According to the measurements of A. V. Hill[6] only a little less than half of this total energy would be available during the actual race. This is drawn from reserves within the body (probably phosphocreatine breakdown) which are replenished in recovery. Therefore, we may estimate the total energy expended during the race at 6 horse power. Only one twelfth of the total energy available is therefore used in overcoming the external resistance.

Some work is also done against gravity in running. The body rises and falls slightly at each step and this amount can also be determined from the moving pictures. This item amounts to an additional 0.1 horse power. Thus out of a total of 6 horse power only 1/10 has been accounted for.

Swinging the Arms and Legs—The Internal Resistance

These results, however, do not tell us the limiting factor—why we can not run any faster. They only tell us how much external propelling force we exert at maximum speed. What we want to know is why we can not expend a

[5] This is the method described by R. M. Sargent, 1926. Proc. Roy. Soc. B, c, 10.

[6] A. V. Hill, "Muscular Activity," Baltimore, 1926.

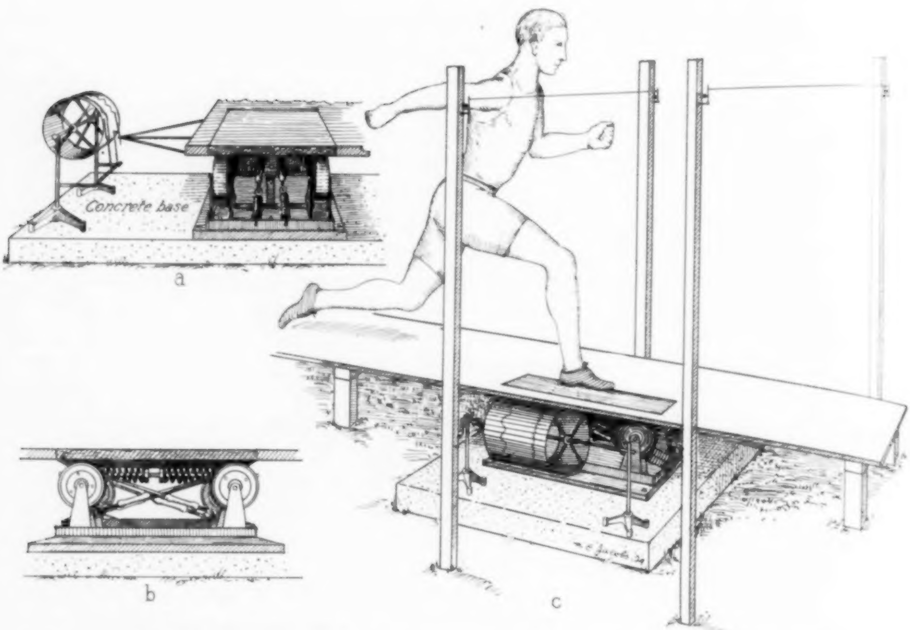

FIG. 3. MOVABLE PLATFORM IN THE RUNNING TRACK FOR THE MEASUREMENT OF THE HORIZONTAL PRESSURES EXERTED AGAINST THE GROUND BY THE FOOT. THE THREADS ACROSS THE TRACK BREAK ELECTRICAL CIRCUITS AND ARE USED FOR THE MEASUREMENT OF THE VELOCITY OF THE BODY. (FROM FENN, *Am. Jour. Physiol.*, 1930.)

greater propelling force—why the propelling force decreases from 50 kgm. at the start of a race to only 5 kgm. at top speed. The reason for this is that increasing energy is needed to move the arms and legs as the speed increases, *i. e.*, to overcome the internal resistance of the parts of the machine. The leg must be moved forward quickly enough to catch the body before it falls and it must be moved backwards quickly enough so that it will not "drag." The limiting factor in running does not lie, therefore, in the external resistance, but in the *internal resistance*.

A simple experiment which any one can do at home convinces one of the difficulty of swinging the legs. During a sprint each foot touches the ground about twice in each second. Try standing on a stool and swinging one foot backwards and forwards as quickly as possible through an arc comparable to that used in running. The author's time was 15 complete swings in 7 seconds or almost exactly twice per second as in sprinting. Most of the effort of running comes from swinging the legs. The small simultaneous push given to the body is a small item in comparison and is largely done by extending the ankle joint.

The emblem of the Isle of Man represents three human legs radiating from a common center like the spokes of a wheel (Fig. 4). This might suggest that the inhabitants of this island in early times had discovered the truth of these observations concerning the work of swinging the limbs and had thus visualized a new and much more efficient method of locomotion in which the limbs could rotate in complete circles. Once endowed with the necessary kinetic energy these limbs could be left to rotate by themselves with further ad-

ditions of energy sufficient only to overcome friction in the bearings. Supposedly the time will come when only an anatomical absurdity of this kind will serve to break the world's record for the 100-yard dash at the Olympic meet. Or perhaps some acrobat will become so proficient at turning cartwheels at constant angular velocity that he can outdistance all competitors.

Thus far the argument has been fairly simple, but the next step demanded an appeal to the cinematograph and much laborious measurement and calculation before the answer was clear. Why is swinging the legs so difficult? Is it because the legs are so heavy that the force exerted by the muscles is insufficient to move them any faster or is there some physiological reason why muscles cannot pull hard against rapidly moving limbs? It turns out that both these answers are correct. The problem lies in apportioning the work between these two factors. *How much of the work of leg-swinging is actually expended in working on the legs and how much in merely trying to work on them.*

We can not measure as yet how much energy a muscle expends in trying to pull against a moving limb, *i.e.*, in trying to shorten rapidly enough to maintain a strong pull against it. We can, however, measure from the moving pictures how much work the muscles actually do against the limbs. For this purpose it is necessary to know the velocity with which they are moving at different times in the running cycle. This is measured by projecting the film picture by picture and measuring the angles of arms and legs. Knowing the velocity with which they are moving the kinetic energy can be calculated from the product of half the mass, m, by the square of the velocity v^2.

In the case of the upper and lower arms and the upper leg it is found that the energy passes through a maximum once during each forward swing and once during each backward swing. The maximum is much higher in the fore arm than in the upper arm because the former is farther removed from the shoulder joint. Likewise the kinetic energy of the lower leg, due to its double rotation around both the knee and the hip and to its greater distance from the hip, is much higher than for the upper leg. Moreover in one double step the kinetic energy developed by one lower leg passes through three maxima; one while the foot is on the ground; *i.e.*, during the backward swing, one when the leg is lifted and the knee flexed behind the body, and one when the leg is thrown forward. All these must be taken into account in calculating the total rate of energy expenditure (horse power) due to swinging the limbs. One of the points stressed in coaching runners is to reduce the flexion of the knee behind the body to a minimum. This reduces the height of the second of these maxima of energy and so eliminates this wasted effort.

By such calculations from the moving pictures of a series of 21 normal college undergraduates running at top speed we found an average expenditure of 1.67 horse power in accelerating the limbs with an additional 0.67 horse power in decelerating them. The former is expended in raising the velocity of the limbs to a maximum both on the forward and on the backward swings and the latter is expended in reducing this velocity again to zero, at the end of each swing. Thus if the runner can develop 6 horse power for the sprint, 2.37 horse power goes to swinging the limbs. The kinetic energy of a leg at full speed is therefore no small item. It serves to hurl footballs over far distant goal posts and if transferred to a 150 lb. man by forcible collision it would raise him bodily 5

inches into the air. Those inhabitants of the Isle of Man knew their physics well.

The argument may now be summarized as follows:

Total energy for complete recovery	13 horse power
Energy available during race	6 horse power
Air plus ground resistance	0.5 horse power
Gravity	0.1
Swinging arms and legs	2.37
Total measured as mechanical work	2.97

We are thus able to account for 50 per cent. of the energy available during the race. Even the Diesel engine is only 35 per cent. efficient. Actually the efficiency of the runner is probably even greater than 50 per cent. for we have left out of our balance sheet altogether the energy used by the heart and that which is used in contracting the muscles of the trunk and the neck to give the body the necessary rigidity. This fixation energy may be rather a large item. Here then is one of the simplest and most well defined of the many biological phenomena which, in the present state of our knowledge, seem to us beyond the realm of possibility. It is Mother Nature's challenge. Can man with all his ingenuity construct a machine which will accept chemical energy, probably derived from the breakdown in the muscle of a (recently discovered) substance phosphocreatine, and will transform this chemical energy into mechanical energy into mechanical work, without an intermediate heat stage, and with at least 50 per cent. efficiency?

How the Limbs Get Ahead of the Muscles

It has been suggested that some of the remaining 50 per cent. of the energy is spent in "trying" to pull against the rapidly moving limbs. It is not yet possible to say definitely how much this energy amounts to, but it is

Fig. 4. Emblem of the Isle of Man. (From Webster's Dictionary, see "triskelion.") Symbolizes a method of escape from the limiting factor in running.

possible to gain a clearer idea of how difficult it is for the muscles to keep up with the limbs as they swing by determining *how rapidly the force falls off in a muscle as its speed of shortening increases.* In isolated muscles this can be measured directly as Hill has done.[7] In human muscles it is possible to measure how the force which the limb can exert against some external dynamometer decreases as the speed of movement increases. This Hill has also done[8] but the results are complicated by the possibility of nervous intervention. I have recently been able to estimate this relation between tension exerted and speed of shortening in man in the following way.[9]

It is a fundamental law of physics that the acceleration with which a body moves is proportional to the forces exerted upon it. Hence if we can determine how the acceleration changes with velocity of movement we shall know how the force changes. The acceleration is the rate with which the

7 "Muscular Activity," Chapter I.

8 "The Maximum Work of Human Muscle and Their Most Economical Speed," A. V. Hill, *J. Physiol.* 56, 19, 1922.

9 These results will soon be published in detail.

velocity is increasing. The velocity is determined by arranging for the arm or leg to drag a pointer along a revolving drum as it swings; then the greater the velocity the steeper the slope of the curve traced on the drum. The acceleration is the rate with which the steepness of the curve increases. The subject flexes his knee or his elbow and tries to extend it as hard as possible against a strong spring balance which measures the force developed. The limb is then suddenly released so that it is free to fly out under the influence of the tension already existing in the muscles. From the drum record which is traced as the limb flies out, the acceleration is determined. It is found that the accelerating force decreases as the velocity increases. By averaging together the records obtained in many experiments it is found that the acceleration and hence *the tension of the muscles decrease 3.2 per cent. when the velocity of shortening of the muscle is 10 per cent. of its length per second.* By the time the limb has moved 4.5 cm, sufficient time has elapsed (about 0.01 seconds) to permit some reflex relaxation of the muscles to take place. Hence this value must be calculated from the record inscribed during the first 4 or 5 centimeters of movement. After moving this distance the muscles are shortening at a rate of about 60 or 80 per cent. of their length per second and accordingly the force has dropped off 19 to 25 per cent.

From these experiments we find that the muscles lose 3.2 per cent. of their tension for an increase in their rate of shortening of 10 per cent. of their length per second. Is this sufficient to account for the difficulty observed in exerting tension against a moving limb?

From the movies the rates of flexion or extension of the knee and hip joints at every moment during the running cycle are known. By reference to anatomical papers the lengths of the lever arms of the various muscles concerned can be known and so the corresponding maximum rates of shortening of these muscles can be estimated. In this way it is found that one of the extensor muscles of the knee, the *rectus femoris,* shortens at a maximum rate of 360 per cent. of its length per second while one of the flexors of the knee, the *biceps femoris,* shortens at a maximum rate of 373 per cent. of its length per second. At these rates of shortening the force lost by the muscles would be 360/10 x 3.2 or 115 per cent. (and 119 per cent.). This approximate figure is sufficient to tell us the story. At the maximum speeds of shortening observed in the body, the muscles would be able to exert no external tension and hence could produce no further acceleration. This, therefore, is the process that sets a limit to the speed of movement.

It is necessary to ask one further question, even though no answer is forthcoming as yet. *What is it that prevents the muscles from exerting tension at these high speeds of shortening?* There would seem to be two possible answers to this question both of which involve fundamental concepts of muscle physiology.

If a muscle exerts tension against an immovable object it must spend energy continuously as long as the tension is maintained. We may describe this by saying that the muscle continuously loses tension at a certain rate and that the energy expended is necessary for the continuous redevelopment of this tension. Eight years ago, while working in Hill's laboratory in London the writer was able to show[10] that when a muscle was shortening it expended more energy, and when it was being stretched it expended less energy than when it was merely contracting without change of

[10] W. O. Fenn, "A Comparison between the Energy Liberated and the Work Performed." *Jour. Physiol.*, 58, 175, 1923.

length. We may describe this by saying that in shortening it loses tension at a greater rate and in lengthening it loses tension at a lesser rate than when stimulated at constant length. Consequently the rate of redevelopment of tension must be greater while it is shortening and less while it is lengthening than when it is of fixed length. The added necessity for redeveloping tension during shortening and the delay in the chemical reactions necessary to supply energy for this process is one of the factors which limit the tension in moving muscles. The other factor contributing to the loss of tension in shortening muscles is the viscous elastic effect studied by Hill. By this we should mean a *mechanical delay* in the development of tension due perhaps to the viscosity of the internal medium of the muscle. Certain structural rearrangements, if only of molecular dimensions, must obviously be required for the external manifestation of tension in a muscle, and these would certainly be interfered with by internal frictional resistance. The exact apportioning of the tension loss in shortening between these two factors is yet to be accomplished. Also we do not yet know how much of the total energy mobilized for the race appears directly as heat due to the inefficiency of the machine. Both of these questions are of great importance for the physiology of muscles.

In spite of these perplexities we shall still have our races and our runners. The less they know about the whys and wherefores of their remarkable machinery the better they will run and all our knowledge probably will not take one fraction of a second off their best times. But we have at least gained a better idea of why every last fraction of a second is needed.

WORD PAINTING

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Descriptive writing in prose or verse is akin to drawing and painting, in that both aim so to clothe an idea which exists in the mind of author or artist that it may be intelligible and pleasing to the public, or at least a part of the public. In either case, the success of the producer is measured by the reality and vividness which he gives to his idea in the mind of the recipient.

In the work of the artist we note two important steps: first, the drawing of the outline or structure; second, the filling in with light and shade and color, to bring out the picture in relief and give to it realism or impressionism, as the case may be. The first is more a matter of mathematics than of art, since the outline must be correct in proportion and perspective. The second is a question of artistic rendering, involving the use of the imagination and of certain tricks of light and color which shall produce the desired effect on the eye of the beholder. The great artist does not paint things as they really are but as they appear, and by a skilful manipulation of certain colors creates an atmosphere and an impression which emphasize his idea.

In like manner the author forms the skeletons of his sentences with nouns and verbs which convey the main ideas, as, "The sun shines," "The wind blows," "The man walks." To elaborate his idea and to produce a vivid impression on the mind of the reader, he embellishes his sentences with adjectives and adverbs: "The wintry sun shines feebly." "The summer wind blows fitfully." "The solitary man walks stealthily."

We may liken the qualifying words to color media, since they give life and form to otherwise vague and incomplete ideas, and as artists vary in their treatment of a theme, using different keys and different color schemes, so authors may vary their interpretations and by the use of different "word colors" produce divers effects on the minds of their readers.

The present paper is an attempt to analyze the use of qualifying words by various writers of prose and poetry and to determine, if possible, the characteristics of their various "color schemes." For the purposes of this study were chosen three English poets, Milton, Tennyson and Keats; three English prose writers, Scott, Dickens and Thackeray; three American poets, Bryant, Longfellow and Whittier, and three American prose writers, Irving, Hawthorne and Poe.

An attempt to include certain essayists, such as Addison, Carlyle and Emerson, revealed the fact that their adjectives could not be classified with those of the poets and writers of fiction, since the ideas presented by the essayists were so much more abstract in their character. You can not well compare a description of an emotion or a virtue with those of people, landscapes and buildings.

In a general way the extracts chosen for study were of two classes: (*a*) Descriptions of outdoor scenery; (*b*) descriptions of indoor scenes, including descriptions of persons present.

The selections were of various lengths, containing all the way from four hundred to three thousand words each, the total number of words from each writer being three or four thousand. A careful count was then made of the adjectives and adverbs in each selection and these modifiers were arranged in classes,

according to their significations. Considerable difficulty was experienced in determining the most rational method of classification and several plans were tried and discarded. The following method was finally chosen and, while not by any means perfect, seems to be fairly satisfactory.

(1) Adjectives of appearance or sight, including color, value (light and shade), form or outline, and texture; (2) adjectives of quantity and place, including size, number, location, motion (this division includes most of the adverbs); (3) adjectives of the senses other than sight, including sound (pleasant and unpleasant), touch, taste and smell; (4) miscellaneous, including time and abstract adjectives (pleasant, unpleasant and neutral), moral and mental qualifications.

It was at first intended to classify sound adjectives as to pitch, time, quality, etc., and to specify under touch such qualities as shape, texture and temperature, but the very limited use of the sense adjectives other than those of sight made this unnecessary. Value is used in its artistic sense to signify light and shade, brilliancy and dimness.

The adverbs are for the most part included in the subclasses of motion and time. Participles used in the sense of adjectives are included in the motion subclass. Sounds are distinguished as pleasant and unpleasant, and silence, or absence of sound, is included in the classification. Time is distinguished as long or short, past or present, and of course includes many adverbs.

All adjectives which have reference to spiritual rather than physical attributes are put in the fourth class. They are subdivided according as they indicate pleasant and good qualities or the reverse. The third subclass of neuter abstract qualities is a sort of rubbish heap for adjectives that refuse to be classified otherwise.

Selections

1. *Milton.*—For outdoor description is selected from "Paradise Lost," Book IV, lines 160 to 268, a description of Eden and of Satan's first visit. This selection mentions the approach of the fallen angel to the outer wall, the view from the Tree of Life and of the river. This was written about the year 1664, some ten or twelve years after Milton became blind. As a contrast to this are chosen "Il Penseroso" and "L'Allegro," both written about 1632, when Milton was a young man and living in his father's house. These are apostrophes to Melancholy and to Mirth respectively.

The extract from "Paradise Lost" is notable for adjectives of texture, touch and smell, and deficient relatively in those of value and sound. The last deficiency is the more remarkable when we consider that in the two earlier selections, "Il Penseroso" and "L'Allegro," adjectives denoting pleasant sounds are relatively numerous. Milton was noted as a musician, and it hardly seems that loss of sight would change his feelings in this respect.

"Il Penseroso" is strong in adjectives of value and weak in those of color, this probably due to the nature of his theme. "L'Allegro," on the other hand, is notable for its color adjectives and for those of pleasant sound; this also might have been expected. In abstract adjectives of a pleasant character, "Il Penseroso" is far in the lead of both the other selections. This may perhaps be understood when we remember that the poem tells of the pleasures of melancholy and not of its pains. It would naturally be assumed that verses written after Milton's blindness had come upon him would be deficient in the adjectives of sight and appearance. Inspection, however, shows the same number of these in the extract from "Paradise Lost" as in the two poems written in his youth.

This may be best explained in the poet's own words:

> but thou
> Revisit'st not these eyes that roll in vain
> To find thy piercing ray, but find no dawn;
> So thick a drop serene hath quenched their orbs,
> Or dim suffusion veiled. Yet not the more
> Cease I to wander where the senses haunt,
> Clear spring, or shady grove, or sunny hill
> Smit with the love of sacred song;[1]

The most noticeable peculiarity of the later poem is the unusual number of adjectives expressing smell or odor, there being twelve of these in a thousand words. When we consider the fact that this class of modifiers is rare and is entirely absent from most of the selections, this exception becomes even more noticeable. Pleasant odors made up in part for loss of light and color.

2. *Tennyson.*—The selections from Tennyson are: for outdoor life, "The Lotus Eaters" and "Mariana" of his earlier poems and an extract from "Maud" (1855), "Come into the garden, Maud"; for indoor and personal description, "The Lady of Shalott" (1832) and the prologue of "The Princess" (1847).

One notices first in these groups the comparative paucity of descriptive words in the two later poems, "Maud" and "The Princess," the percentage being smaller than in any other selections listed. On the other hand, "Mariana" and "The Lady of Shalott" contain more than the usual number of adjectives. It is to be noted, however, that this number is swelled by repetitions and refrains as is the case with the word "aweary" in the former poem.

The lack of adjectives in some of Tennyson's poems is accounted for by the fact that he frequently uses nouns in a descriptive fashion, especially color-nouns. All the extracts analyzed show a marked deficiency in sense adjectives other than those of sight. "The Lotus Eaters" and "Mariana" have an unusual number of abstract adjectives of an unpleasant sort, while in "The Princess" pleasant ones are more numerous. These differences are due to the subject rather than to any peculiarity of the diction.

A rough comparison of Tennyson with Milton indicates that the latter is more fertile in artistic and sensory adjectives, while Tennyson leads in the use of abstract and subjective modifiers.

3. *Keats.*—Two selections from Keats were analyzed, one of three hundred lines from Book I of "Endymion" for outdoor description, and one of seventeen stanzas from the "Eve of St. Agnes." The passage from "Endymion" describes the scene of the poem on the sides of Latmos.

Contrary to expectations, these proved to be less rich in adjectives than the selections from Milton or the earlier poems of Tennyson. "Endymion" is remarkable for the number of adjectives of color, texture and size, and the "Eve of St. Agnes" for those expressing pleasurable emotions. In general, it is to be expected that natural scenery will require more objective modifiers for its description, while indoor scenes, with their actors and actresses, will call for the abstract or subjective. The extract from "Endymion" contains six adjectives expressing odors and, with the exception of the extract from "Paradise Lost," takes the lead in this respect.

4. *Bryant.*—Bryant is generally considered a "nature poet" and is by some compared to Wordsworth in this regard. Several of his shorter poems were selected for comparison, the "Fountain," "The Rivulet" and "The Prairie" for the nature group, "The African Chief" and "The Damsel of Peru" for personal description. The dates of their production are unknown to the writer.

The "Fountain" contains thirty-one color adjectives in a total of about a thousand words, more than double the

[1] "Paradise Lost," Book III, lines 22–29.

proportion found in any of the other poems examined, either English or American. About one half of the modifiers in this poem belong to the artistic or sight group, an unusual ratio. "The Rivulet" and "The Prairie" have a large number of time modifiers, more than one fourth being of this character in the former poem. Both these poems are rich in descriptive words, "The Rivulet" having the largest ratio of any selection analyzed.

"The African Chief" and "The Damsel of Peru" are not remarkable as descriptive selections. The former has many unpleasant abstract modifiers and the latter a large proportion of pleasant sounds and qualities.

The five selections chosen contain no adjectives of smell and only two of taste.

5. *Longfellow.* — A selection from "Evangeline" contains about 2,500 words and was chosen to illustrate nature description, being a picture of the bayous of Louisiana, while "Lady Wentworth" and "King Robert of Sicily" supply the personal coloring. The percentage of modifiers is about the same in all three poems and compares favorably with those of the English poets. "Evangeline" was the earlier poem, written about 1847, fifteen years earlier than the other two. It is remarkable for adjectives of size, location and motion, rather than those of color or value. Over one third of the whole number of modifiers belong to the "geometric" class. Pleasant sounds are noticeable, while pleasant and unpleasant emotions are equally represented in the abstract modifiers.

In the last two selections, "King Robert" and "Lady Wentworth," the "sensory group" is almost negligible and the other three groups about normal. Pleasant adjectives largely exceed the unpleasant in "Lady Wentworth," but in "King Robert" about one fourth of the whole number of modifiers are unpleasant.

6. *Whittier.*—Extracts of 2,600 and 2,900 words, respectively, from "Snow-Bound" and from "The Preacher" serve to illustrate the Quaker poet's powers of description. The selection from "Snow-Bound" contains the picture of the farmhouse and its surroundings after the storm. The proportion of descriptive words is about the same as in Longfellow, but Whittier uses more abstract adjectives than the other poet, more than a third of the total number in each poem being of this group.

"Snow-Bound" is rich in the artistic adjectives, while in "The Preacher" those of location and motion predominate. Pleasant adjectives are more numerous than unpleasant in the former poem, but in the latter they are evenly balanced.

Comparing the averages for the six poets just considered, we find them to rank as follows in the percentage of descriptive words:

Bryant	14.1	per	cent.
Milton	13.8	"	"
Whittier	11.9	"	"
Longfellow	11.5	"	"
Keats	10.9	"	"
Tennyson	9.2	"	"
General average	11.9	"	"

Bryant and Milton are in a class by themselves in this particular, while Tennyson is low, as before explained, because of his preference for color nouns.

Prose Writers

In order to make a fair comparison it was found necessary to confine the analysis to writers of fiction.

7. *Scott.*—"Anne of Geirstein" was chosen for outdoor description and "Ivanhoe" for indoor. The first extract narrates the approach of Arthur and his father to Geirstein and describes the Alpine scenery. In the second selection appears the description of Athelstane's banquet hall and of his household. Both descriptions are weak in

color adjectives and strong in those of form, size and texture. Geirstein is particularly rich in modifiers of location and motion. Probably this is due to the nature of the Alpine scenery portrayed. In Geirstein the greater number of abstract modifiers are unpleasant, while in Ivanhoe the reverse is true.

When we remember that the first selection is a description of wild mountain scenery and of the difficulties and dangers of travel and that the second passage portrays a feudal banquet hall and the assembly of nobles and retainers for a feast, we can easily account for this difference.

On the whole, the Geirstein is richer in adjectives, but when we find only five words of color out of a total number of 331 modifiers, in a description of natural scenery, we must conclude that the writer is not affected by color as are most of us.

8. *Dickens.*—For nature description a selection from "Old Curiosity Shop" is chosen, and for indoor life an extract from "Pickwick Papers." The first contains a part of the travels of Little Nell and her grandfather, and the second tells of the Christmas party at Wardles'. The outdoor description, in the number and character of its adjectives, corresponds closely to that of Geirstein just noticed, and the observations made concerning Scott's description will apply here. A general weakness in the sensory and artistic modifiers and a strong predominance of those pertaining to size and location and to abtract qualities characterize both.

Compare Keats or Bryant, using thirty-one color adjectives each, or Whittier using twenty-six, with the five and nine respectively of Scott and Dickens. Pickwick naturally contains a large proportion of abstract modifiers—more than half of the whole number used. The pleasant adjectives outnumber the unpleasant about two to one. Thirty adjectives of size and forty-three of time emphasize the tendency of Dickens to contrast the big and little, the old and new.

9. *Thackeray.*—Thackeray's description of Killarney in the "Irish Sketch Book" is used for one example and his account of Charles Honeyman's hermitage in "The Newcomes" for the other. Thackeray redeems himself by using no less than sixteen color adjectives in the first selection. As is the case with Dickens and Scott, the greater number of his descriptive words pertain to texture, size, location and motion, 138 out of 294 in this category. Pleasant sounds and pleasant emotions predominate.

Six adjectives of smell are found—an unusual number.

10. *Irving.*—A description of the journey from Seville to Granada in the opening chapter of "The Alhambra" has been chosen to illustrate Irving's description of natural scenery, and "Christmas Eve at Bracebridge Hall" has been selected for the indoor picture. In both these the author shows his fondness for subjective rather than objective study, nearly one half of his adjectives being of an abstract character. Adjectives of color and value are almost entirely absent, while the geometric modifiers are numerous.

In "The Alhambra" eighty-three adjectives of the pleasant and unpleasant emotions show the tendency of Irving to moralize. In both selections sensory adjectives are wanting, if we except a few descriptions of sound. In "Christmas Eve" seventy-three modifiers indicative of time as against forty-three in a similar picture by Dickens, just quoted, show that Irving has his English contemporary beaten on his own ground. In geometric words of size, number, etc., Irving also has the lead by 50 per cent. It is interesting to note that the earlier selection is richer in modifiers than one from "The Alhambra" written a dozen years later.

11. *Hawthorne.*—Hawthorne's "Mar-

ble Faun" and his "Mosses from an Old Manse" were chosen for illustration. An extract was taken from the former describing the Suburban Villa in Chapter VIII, to serve for outdoor description, while the description of the Old Manse itself answers for the indoor. The emotional adjectives predominate in both descriptions, particularly those of age and time. This is natural in view of the themes treated. There is little difference between the two selections as regards the classes of modifiers used. Both are relatively weak in artistic and sensory adjectives and strong in those of size, location and motion. In this respect they are much the same as the selections from Irving just noticed. There is much of sentiment in them all and a tendency to moralize on the past.

12. *Poe.*—The description of the "Domain of Arnheim" from the tale of that name was chosen to illustrate Poe's power of outdoor delineation. His account of Usher and his surroundings in the "Fall of the House of Usher" shows the character of his indoor work. In Arnheim we find a wealth of adjectives exceeding that of any prose writer chosen and equaled only by Bryant among the poets. The larger number of these are in the first two groups, the artistic and the geometric. All these are well represented, while sensory adjectives are few in number and the abstract modifiers are only moderately represented. But ten adjectives of an unpleasant character out of a total of 281 show that Poe could be cheerful when he wished.

Usher has but few color adjectives and more of light and shade. It differs in a marked degree from Arnheim in that nearly half of the adjectives are in the emotional group and that the unpleasant ones are in the majority. Sixty-four adjectives of this last character stamp Usher as preeminently a sad tale. It is not, however, as rich in adjectives as a whole.

Comparing the six prose selections as we have those of poetry, the writers stand in the following order as regards the percentage of adjectives used:

Poe	15.1	per cent.
Hawthorne	13.7	" "
Dickens	12.3	" "
Thackeray	11.5	" "
Scott	11.4	" "
Irving	11.4	" "
General average	12.6	" "

Poe is the leader in this list, as probably was to have been expected, with Hawthorne a good second. Furthermore he leads all the authors quoted, prose writers and poets included. A comparison of the averages for writers

PERCENTAGES OF ADJECTIVES
1. Outdoor. 2. Indoor.

Name of writer		Artistic, per cent.	Geometric, per cent.	Sensory, per cent.	Abstract, per cent.
Milton	1	35	22	18	25
"	2	35	17	16	32
Tennyson	1	29	21	11	39
"	2	33	32	6	29
Keats	1	34	19	15	32
"	2	26	9	20	45
Bryant	1	30	25	14	31
"	2	29	7	23	41
Longfellow	1	21	35	13	31
"	2	30	28	7	35
Whittier	1	26	24	12	38
"	2	21	26	10	43
Scott	1	24	38	5	33
"	2	25	30	6	39
Dickens	1	18	41	7	34
"	2	15	25	8	52
Thackeray	1	18	42	9	31
"	2	18	31	8	43
Irving	1	21	30	5	44
"	2	12	33	4	51
Hawthorne	1	18	34	5	43
"	2	16	33	6	45
Poe	1	31	41	3	25
"	2	17	28	3	52

of prose and poetry shows little difference. In fact, the poets have slightly the disadvantage, their general average being 11.9 per cent. as against 12.6 per cent. for the writers of prose.

Perhaps after reading this analysis one is tempted to say, "Well, what of it?" Some literary critics are inclined to regard the use of adjectives with suspicion and to condemn those writers who are too liberal in this respect. This is a matter which we will have to leave to purists to decide. The present article shows the difference in the number and in the character of such modifiers as used by some of the leading writers of fiction and of poetry in England and in this country. It is apparent that the kind of adjective used is often due to the character of the subject, but even then the style of the author has its influence, as witness the two descriptions of a Christmas gathering by Dickens and by Irving. The most interesting comparison is that of the classes of modifiers used by the various writers, whether of color, of shade, form, texture, etc.

The accompanying table gives the percentages of each class of adjectives, *i.e.*, artistic, geometric, sensory and abstract, as compared with the whole number of modifiers in each selection. Consultation of these figures will verify statements made in the preceding text. The complete table of numbers of the various modifiers is too long to include in this paper.

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THE AGE OF THE EARTH

By Professor A. C. LANE

TUFTS COLLEGE; CHAIRMAN OF THE SUBCOMMITTEE OF THE NATIONAL RESEARCH COUNCIL ON ESTIMATION OF GEOLOGIC TIME

SOME time ago when I had the pleasure of addressing the innumerable multitude of a radio audience I was rewarded by one of my hearers giving me a more correct location of a specimen to which I referred. I hope that this time one may write me as consultant in the national library in Washington and give me the author of this little poem which expresses in four lines the three main ways in which we measure time:

And still the hands around the dial creep;
And still the burning sands within the glass do fall;
And still the water clock doth drip and weep;
And that is all.

The clock dial and the hour-glass which I used vainly to shake when I practiced the piano by it are familiar, but the water clock which measured time by the slow accumulation of water, drop by drop, is now obsolete. It was a method used from classical times well through the middle ages. It may represent regular recurring paroxysms, while the first method represents the progressive, and the second the periodic methods of measuring time.

It would take many more than twelve minutes to describe the many more than twelve ways through which men have sought to gain an idea of the time it has taken to fashion the earth—by the wearing back of Niagara Falls, by the building forward of dunes and deltas, by the accumulation of salt in the sea or of oxygen in the air. But they all may be compared to the progressive slipping away of the sands of time, as in an hour-glass, or to the periodic revolutions of the hands of the clock or of the earth around the sun, or to the regularly recurrent paroxysms of the water clock. Many of the methods can not give very accurate results, for they assume, as they all must, that from the present rate of activity we can infer the past. But there is one action which seems to go on most uniformly and does not seem to be affected by any temperature or pressure likely to occur at the surface of the earth. It is that which depends on the explosion of atoms like radium.

Many of you have wrist-watches on which the figures are luminous. Some evening take a pocket lens and look at these figures. You will find that the luminosity is not a steady and quiet one but that it quivers and is made up of a shower of sparks like a bursting rocket. Of course, this must be done in the dark. In the daytime the eyes will require some minutes to grow sensitive. In the evening after dark it will probably be only a minute or two.

Each of the sparks you see represents the explosion of an atom, like the explosion of a kernel of corn in a corn-popping machine. The result of that explosion is in part a gas, the gas helium which fills our dirigibles. This corresponds to the steam given off by the pop-corn.

The atom that explodes is of some rare metal. What finally remains permanent is a substance so much like ordinary lead that it is one of the most difficult problems of physics and chem-

istry to separate it from ordinary lead. In fact we remember what Mark Twain reports of Adam at Niagara Falls that when Eve brought him a toad to name, he said, "It looks like a toad and it jumps like a toad so we will call it a toad." We will call it radio lead.

The metal best studied is uranium, which is used to make the yellow glasses that protect our eyes from glare. In the course of the change from uranium to radio lead a number of other rare elements are produced and eight atoms of helium are given off. One of these rare elements is one of the most precious things in the world, radium. Therefore much study has been given to this series of changes. Now if in a pop-corn machine we knew how fast the kernels were popping we could tell from the number that had popped how long the machine had been running. If we take of a mineral or salt that contains only about 1 per cent. of uranium a weight equal to that of paper from an eyelet hole (0.262 mg) we should get an average of about two flashes every ten seconds (98,000 flashes per gram of uranium). Since there are about eight flashes for every atom of uranium that explodes, if we divide by eight and multiply by the thirty-one million (31,556,926) seconds in a year we get the number of atoms of lead produced each year—about a million (840,000). But even in the small quantity of uranium we have assumed there are 6,650 million million atoms, so that it takes between four and five thousand million years for the uranium to be half changed to lead, and between seventy and eighty million years for the amount of lead to reach 1 per cent.

Moreover, with regard to the exploding atoms it is found that the more rapidly they explode the further are the particles thrown, and that these may produce a discoloration or halo around the decaying mineral. These halos are often found in the rocks, and if the rate of explosion had varied much in the past the size of the halos would too, whereas the older halos are little if any greater than the recent ones. Thus the rate can not have changed much since Cambrian times. Holmes estimates that the uncertainty may be 3 per cent.

One of the sources of uranium and radium has been the yellow mineral carnotite, of Colorado. This was formed only in the last finished geological period and the proportion of lead to uranium is less than one in a hundred. Thus it is less than seventy million years old. Minerals which were formed at about the time the Appalachian Mountains were folded have more lead in proportion, something like one part in forty or fifty, and are more nearly 200 million years old. A black coaly substance known as kolm from the oldest rocks (the Cambrian) that contain well-marked fossils has the purest radio lead known. The proportion to the uranium is (.059) one to twenty, and it should be 440 million years old; and in still older rocks found before we have any well-marked signs of life we find minerals whose ratios are as high as one in ten or even one in four, indicating ages of 1,570 million years and perhaps older.

This sounds very simple and the theory is indeed quite simple. To find the rate at which uranium is changing to lead we have only to count the sparks. You can not do that with your wrist-watch. They are too abundant. But by taking a small enough quantity they can be counted. How many atoms there are in a gram of uranium is easily found from well-known chemical facts, and it is then comparatively simple from the proportion of radio lead to uranium to tell how many years ago the mineral was formed. The accuracy would depend on that of the analyses and the count.

However, there are certain ifs, as there always are in every scientific result. Science only reaches a certain probable degree of accuracy. One of the difficult

problems is to determine how much is really radio lead and how much may be lead produced from some other source. Another is what the chances are that, since the mineral formed, uranium or lead may have been leached out of it or added to it. Another question is whether the rate of change of uranium to radio lead has always been the same. Finally, where did it come from in the first place? These are questions which we can answer with a considerable degree of probability except perhaps the last one. Always, however, we find that around the enlarging area of our knowledge there is the even greater circumference of our ignorance. For every progressive and evolutionary process starts with initial conditions for which it does not account. The sands of the hour-glass would cease running down except that from time to time the hour-glass is turned over.

We can, however, say that if uranium had been changing to lead at the rate it is now changing, and if this process had been going on for not merely two or three billions of years but tens of billions of years, we should have more lead in the crust of the earth than we have at present.

In this process of atoms flying apart heat is also given off. From uranium enough is generated every hour to heat its own weight one degree Centigrade. If the whole earth had as much of this going on as granites have, it would be heating up instead of cooling down and might be getting ready to explode. However, not only is it probable that these atoms are more concentrated near the surface of the earth (since we do not find them so much in meteorites) but it has been well suggested by Joly and Holmes that just as the steam of a teakettle would periodically lift up the lid, or as a geyser periodically discharges, even so any excess of heat generated gets enough to overcome the crust resistance every twenty or thirty million years and then produces a period of volcanoes and mountain building and that thus we have alternate periods of rest and activity. Holmes counts eighteen of these since the deposit of the Swedish Kolm 440 million years ago.

It is a task for the geologist to work out these cycles and see if they have about the length (twenty-four million years) indicated. There are numerous ways of so doing. For instance, as we tell the age of a horse by the wearing down of his teeth, so we can estimate the age of mountains. The younger mountains, the Himalayas and the Rockies, are higher, and in the older mountains like the Appalachians and those around Lake Superior the folds have been beveled off until it is literally true that the valleys have been exalted and the hills laid low. Estimating the load caused by the rivers we may estimate how fast this action has been going on. It has been estimated that 15,000 feet of strata have been removed from the region of the Rockies and the Grand Canyon of the Colorado in the last two of Holmes's periods at a rate of perhaps one foot in 3,000 years. This would make the length of these two cycles forty-five to sixty million years. The thickness of the beds deposited may also be used to base an estimate.

Moreover, as we can tell the age of a tree by its rings (note the dates on the section of the big tree in front of the National Education Association building on 16th Street, Washington, D. C.) and by the thickness of the rings distinguish good years and poor years and sun-spot cycles, and as by the rings of its big trees the climatic changes of California have been studied by Ellsworth Huntington clear back to the famine that took place in the days of Elijah, even so in fossil trees and stalactites and many deposits there is a variation in their character at different seasons of the year. The clays from melting glaciers are finer

in the winter, the layers of coal and oil shale laid down in certain seasons of the year Bradley finds are richer in resins. And again, sun-spot cycles and cycles of good and bad years may be recognized. Moreover, Gilbert and Stamp and Bradley seem to have identified a banding due to a cycle of 26,000 years during which the earth changes from having its northern winter when it is nearest the sun to having it when it is farthest from the sun and back again. Thus we may estimate directly the time required to deposit certain thicknesses of beds. Bradley thus comes by an entirely different way to an estimate of the length of the last two of Holmes's periods not widely different (2 x 27,000,000 years).

Thus if we "speak to the earth" as commanded in the book of Job it will teach us that in very truth, as the Psalmist says, a thousand years are but as a day and as a watch in the night of the divine economy.

DOING SOMETHING ABOUT EARTHQUAKES

By Captain N. H. HECK

CHIEF OF THE DIVISION OF TERRESTRIAL MAGNETISM AND SEISMOLOGY, U. S. COAST AND GEODETIC SURVEY

LAST July there was a severe earthquake in southern Italy which caused much damage to property and loss of life. Earthquakes and volcanoes have long been associated in the public mind, and it is, therefore, of special interest that Dr. Malladra, director of the Vesuvius Observatory, states that while his building was badly rocked by the earthquake and was saved from destruction only because the various parts were chained together, there was no volcanic activity at the time of the earthquake.

The destruction caused by this earthquake has a possible lesson for us even though the conditions are quite different. The buildings have thick walls of field stones and poor mortar and thick roofs, the thickness being intended to keep out the heat. Timber is scarce and the roof supports are weak. There is, therefore, the combination of great weight and lack of strength, an ideal arrangement for producing maximum earthquake damage. For many years destroyed houses were rebuilt in exactly the same way, to fall in the same manner in the next earthquake. This is no longer the case and the present Italian Government, through improved building codes and cooperative arrangements in rebuilding, has done much to improve the situation.

In our country there was a period of helplessness when there was even an attempt to deny the existence of earthquakes, but such an attitude is disappearing before the new possibilities which are opening up every day.

A broad gauge attack on the earthquake problem is now going on in this country, Japan and other parts of the earth. It includes practically every field of interest from interpretation of seismograph records to design of dams and other structures. With all its comprehensiveness there is one serious gap—we do not know exactly what goes on in the central region of severe earthquake. Observers tell us what they have seen, but it is well known that eye-witnesses under stress are unreliable, however honest they may be. The records left in buildings and in the earth itself are invaluable, but they do not tell us just how the results were brought about. There are almost no records of an earthquake of the greatest intensity obtained within the region of severe damage, though a few have been obtained in Japan.

The engineer is now demanding this information from the seismologist. The latter can obtain this, and he is getting ready to do it by modifying existing seismographs so that they will give the

desired record and avoid destruction unless the building containing them is destroyed. Effort is being made to secure the most complete record possible at the lowest cost. The seismologist expects that in addition to furnishing what the engineer desires he can find how earthquakes are propagated from the central region outward.

Even with instruments in operation it is going to be hard to interpret the records. All evidence, such as the way cemetery monuments fall or twist on their bases, is that the earthquake activity is complex. Persons are sure that they have seen waves roll across alluvial ground like the ground swell of the ocean and at a moderate speed, but there is no instrumental record of such waves and there is no theory to fit them.

It therefore seems that any attempt to use the records of strong motion instruments directly will fail. The problem must be approached indirectly. There are now being obtained in southern California, a region of numerous small earthquakes, complete records by sensitive instruments of all that occur. The records give the time required for the earthquake waves to travel to the instrument, yet it is difficult to locate the earthquakes with the desired accuracy. The reason is best explained by reference to so-called seismic prospecting. Somewhere in Texas, for example, a great blast is fired and the waves passing through the earth are recorded by seismographs. The different geological formations affect the path and behavior of the waves, and these effects make it possible to trace the formations.

The fact that surface layers affect the earthquake waves is an advantage in finding oil, but a detriment to earthquake study. Many observations are being made, and the results should be useful in the case of severe earthquakes.

The records of a distant station show that much of the complex activity of the central region has disappeared with distance from center, and that even though there be several centers of the shock only the greatest outburst sends energy to a distance. The simplification of the distant record gives another possible line of attack, that is, to close in on the earthquake from the outside, so to speak, and extract from records taken at a moderate distance information that is probably concealed in them. This field of study is immediately available in the records of many stations.

In addition to the earthquake waves there is good evidence from observations in Japan that the earth tilts in the central region of an earthquake during the entire period from one earthquake till the next, first in one direction and then in the other, and the claim is even made that sudden changes in the tilt just before an earthquake make it possible to predict the occurrence some time in advance. A device known as the tiltmeter has been designed and put in operation, and interesting results have already been obtained. Since Japan is a very much more active earthquake region, its tilts are probably greater than anything that would be found in the United States. However, it is quite important to study by this method regions where earthquakes have occurred in the past. An instrument of different design from the Japanese is in the process of development, but in the meantime Mr. John R. Freeman, a prominent civil engineer, has made it possible to start this study at Stanford University by bringing a tiltmeter from Japan and lending it to the institution for this study.

Since earthquakes of great severity are rare in this country and since we do not know where they may occur, it might appear that we might install instruments and then wait years for records. This can be avoided by making the instruments sensitive to a moderately strong shock, of which there is a sufficient num-

ber, and besides, regions can be selected where strong earthquakes are fairly frequent. Parts of the Imperial Valley in California will meet this requirement if history is a guide.

At best it will be some time before the desired information is in the hands of the structural engineer, and rightly, the engineer is not waiting for it. He is designing large buildings, bridges and dams as best he can for earthquake stress. There has been going on at Stanford University for several years investigation by means of a shaking platform of stresses of structures under movements resembling earthquakes, and also studies of foundation materials subjected to similar vibrations. The platform, a heavy steel structure, is set into vibration by suitable apparatus and, except in the vertical direction, is capable of closely imitating earthquake motions, provided it is known what these are. An immediate use of new information along this line is therefore indicated. Other engineering studies are being made and the elaborate work in Japan along these lines is being followed.

The activities that I have described are being carried on by a large number of organizations, among which are included the Carnegie Institution of Washington, the universities of California, the Massachusetts Institute of Technology, the U. S. Bureau of Standards and the Jesuit Seismological Association. The part which the Coast and Geodetic Survey, the branch of the government charged with seismological investigation, is being asked to play is the installation and operation of the additional instruments and the physical interpretation of the results—work that the federal government is specially qualified to undertake. The interpretation of the results in terms of principles of structural design is for other organizations.

The present state of civilization is a measure of the success with which man has dealt with his environment and fitted it to his needs. There have been many recent evidences that he has not entirely succeeded. One of the efforts of the future should be to cut the loss when nature exerts its powers which are beyond the control of man.

IN DEFENSE OF INSECTS

By Dr. FRANK E. LUTZ

CURATOR, AMERICAN MUSEUM OF NATURAL HISTORY

For hundreds of years there has been a case before the court of public opinion. It is the case of Insects *vs.* The People. From the nature of things, the insects have had nothing to say about it, and unfortunately they have had very few witnesses or active advocates on their side.

One of the charges against insects is that they destroy or appropriate to their own use about 20 per cent. of our fruit crop. In this connection I beg to present to the court the following hypothetical question.

Suppose we had never had any apples, pears, plums, peaches, oranges, strawberries or anything of that sort. Suppose, however, that a group of strangers brought us delicious samples of a great variety of such fruits and told us that they, the strangers, could make it possible for us to grow all these things. Suppose that, in return for this possibility which only they could grant, they asked that a 20 per cent. commission be paid to their relatives. Does the court think that this would be an unfair proposition? I am sure that we would be glad to accept the bargain and then, later, we would try very hard to beat the relatives out of their 20 per cent.

Although I have stated this in more

figurative language than science is apt to use, it expresses rather exactly the relation between insects and our fruit crop. There is no disputing that certain insects do immense damage, in the aggregate, to our orchards, but it is not fair to forget that we would not have any of those orchards if it had not been for other insects that carried pollen from flower to flower, enabling the plants to set the seed in connection with which the fruits develop.

This process of carrying pollen from one flower to another is called cross-pollination in contrast to self-pollination, the process by which certain flowers fertilize their seed with their own pollen. Whatever may be the possibilities of self-pollination either as a regular practice of some plants or as a last resort with others, cross-pollination is exceedingly important in the biology of the higher plants. Plants with inconspicuous flowers, such as the grasses, and trees like maples and oaks secure cross-pollination by the inefficient, wasteful method of producing vast quantities of pollen and allowing the wind to blow it over the landscape on the chance that here and there a grain will fall on another flower. Plants such as our fruit trees and berry bushes have flowers which are attractive to hundreds of kinds of native bees, to flies, to butterflies and to other insects. These insects, flying directly from flower to flower, accidentally so far as they are concerned, carry pollen on their bodies and bring about the cross-pollination which makes possible future generations of the plants visited.

If we were asked what fabrics we owe to insects most of us would quickly mention silk, but we would be likely to stop there. In the court of public opinion we have heard much about the cotton boll weevil, the pink boll worm and perhaps half a dozen other insects which injure cotton plants, but mention is rarely made of the scores of different kinds of insects busily flying from cotton flower to cotton flower carrying the pollen that enables the plant to set the seed from which we get not only one of our most important fabrics but a literally astounding lot of by-products made from cotton-seed.

Linen in all its varieties is woven from flax, the fibers of insect-pollinated plants. But the fabric which shows in the most interesting way both the complexity of biological relations and the fundamental importance of pollinating insects is wool.

Sheep may be raised exclusively on grasses, such as timothy, that are wind-pollinated, but no practical sheep-grower would try to do it. He wants clovers of some sort, and all kinds of clover, including alfalfa, are insect-pollinated. The sheep-growers of New Zealand imported red-clover seed to improve their pastures. The red clover grew, but the New Zealand sheep-men could not get any seed from their clover plants for the next year's crop because New Zealand did not have the proper insects to pollinate red clover. Bumblebees were introduced from England. These insects became established in New Zealand and are now year after year pollinating clover, making possible continuous and rich grazing for the New Zealand sheep. Just as we never miss the water till the well runs dry, so we in America have most thoughtlessly taken our clover for granted and have overlooked our debt to the native insects which have made it possible.

Of course what is true of wool is true of the mutton which it covers. Also, the same thing is true of cattle, the beef we eat, the milk, the butter, the cheese and even the leather on which we walk.

I am certain that any one who has not already done so—and that means practically every one—will be surprised at the long and important list he can draw up of things which we owe to these pollinating insects. Every important vegetable in your garden, except corn, came

directly or indirectly from a seed that was fertilized by pollen which insects carried. Also your roses and the other beautiful flowers, cultivated and wild. The tobacco you smoke, if you do smoke. The coffee, tea and cocoa that you drink. These are just some of the things we owe to flower-visiting insects.

But even wind-pollinated plants must have good soil in which to grow. Darwin rightly praised the soil-making activities of earthworms and became their most effective press agent. Risking the false impression that I think the value of earthworms is overrated, I would like to point out that ground burrowing insects are more widely—in fact, universally—distributed than are earthworms, that they are more numerous in any given locality and that they are much more active. Furthermore—and this is a generally overlooked fact—an additional reason for their being more effective soil-makers than earthworms is that they carry beneath the surface not only decayed leaves but rich nitrogenous plant-food such as manure and the dead bodies of animals.

Time will not permit even a sketchy continuation of this line of thought, but perhaps you are already about to ask how land plants of any kind ever existed without insects. Others have asked that question, and a part of the answer is that geological history shows that there was no extensive growth of land plants and no flowering plants at all before insects became well established on earth.

Let us barely mention one or two other items in our tremendous debt to insects. Do you like trout fishing? What do you try to imitate when you tie brightly colored things to your hooks? What makes up practically the entire food of our fresh-water fishes? You know the answer. You owe your fishing to insects.

Do you enjoy the song and the sight of birds? Some of these birds are insectivorous. Others are seed-eaters, but since even the seed-eaters are largely indebted to insects for the seeds they eat, you are indebted to insects for the birds themselves.

Birds are of immeasurable value to us in their beauty of sight and sound, and this value, which is real, should be a sufficient reason for their protection, allowing us to drop the sordid and, as we now know, largely fictitious reason that they stand between us and the menace of injurious insects.

Not more than half of one per cent. of the tens of thousands of kinds of insects in the United States are now seriously injurious to man or to his property, and even the best of birds are not economic entomologists distinguishing between man's insect enemies and his insect friends.

Of the relatively few kinds of insects that are now our serious enemies practically all have been brought here by man from foreign countries. Why are these introduced insects so injurious here although they were not particularly injurious in their native homes? Because birds kept them in check there? Not at all, but because they were kept in check by other insects that were not brought to this country with them. The outstanding feature of modern economic entomology is the discovery that our greatest protection against insects which are either potentially or actively injurious is the host of other insects which are the special enemies of those that we rightly fear.

How, then, stands the case of Insects *vs.* The People? Some insects are, from the view-point of the people, undoubtedly guilty of great damage. It is right that we should do everything in our power to control these guilty kinds. But it is not right that we should condemn all kinds because of a few. Furthermore, it would clearly be wise for us to learn more about our insect friends and to cultivate their friendship more carefully.

THE BEGINNING OF A SNOWFLAKE

By Dr. JOHN MEAD ADAMS

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THE lacy beauty of natural snowflakes, seen either in the originals or in the well-known photographic collections of Bentley[1] and others, has attracted the attention and held the interest of almost every one. The endless variety of detail, subordinated in most cases to the requirement of sixfold symmetry about an axis, stimulates the imagination and affords a satisfying example of diversity in unity. To the scientific inquirer, however, these pretty variants of a common pattern present some prosaic questions. What are the physical conditions which govern the making of these designs? Temperature, humidity, electric field, and the time-rates of variation of these quantities, would seem to exhaust the list of relevant circumstances, as far as conjecture can penetrate. Can the rôle of each of these be ascertained? May we hope eventually to be able to read, in a natural snowflake, the sequence of the atmospheric conditions through which it has passed, and so obtain access to a great mass of meteorological information not otherwise available? Might it become possible finally to influence the precipitation of snow on a given area? Such questions as these were the will-o'-the-wisp luring one experimenter into a field quite untilled before, though it had been open to cultivation ever since the invention of the microscope.

The precipitation of moisture, either rain or snow, from the atmosphere is believed to depend on the expansion and consequent cooling of a body of moist air, subject to the condition that no heat shall reach it from the outside during the process. This condition is always satisfied in the movements of large masses of air. The artificial production of rain by this method in the laboratory is a simple experiment—one which has been turned to notable account by C. T. R. Wilson.[2] It is almost equally simple to make a laboratory snowstorm by the same method, but the product is so short-lived that all attempts to preserve it for study have been unsuccessful. In both cases there is a great tendency of the precipitated cloud to reevaporate at the end of the expansion. The refinements introducted by Wilson reduced this tendency, in the rain-cloud, to relative unimportance. In the snow-cloud, however, reevaporation remains dominant in spite of all efforts to minimize it, chiefly because of the smaller density of vapor involved and the greater difference of the temperature between the expanded air and the chamber walls, which of course do not follow the rapid cooling of the contained air. This method of creating snowflakes in the laboratory was abandoned reluctantly and only after an exhaustive course of experimentation extending over eight years.

The problem was solved[3] by using a process which probably occurs more rarely in nature, but which is better adapted to laboratory conditions than the one discarded. It consists simply in mixing two streams of air, one of them dry and cooled well below the freezing temperature, the other moist and warmer. When these two streams are mingled in the correct proportion, a supersaturated atmosphere results in which precipitation occurs spontaneously, and since the heat liberated is not sufficient to raise the final temperature of the mixture to the melting point, the

[1] *Nat. Geog. Mag.*, 43, p. 103, 1923, and elsewhere.

[2] Roy. Soc. Phil. Trans. A, 189, p. 265, 1897.

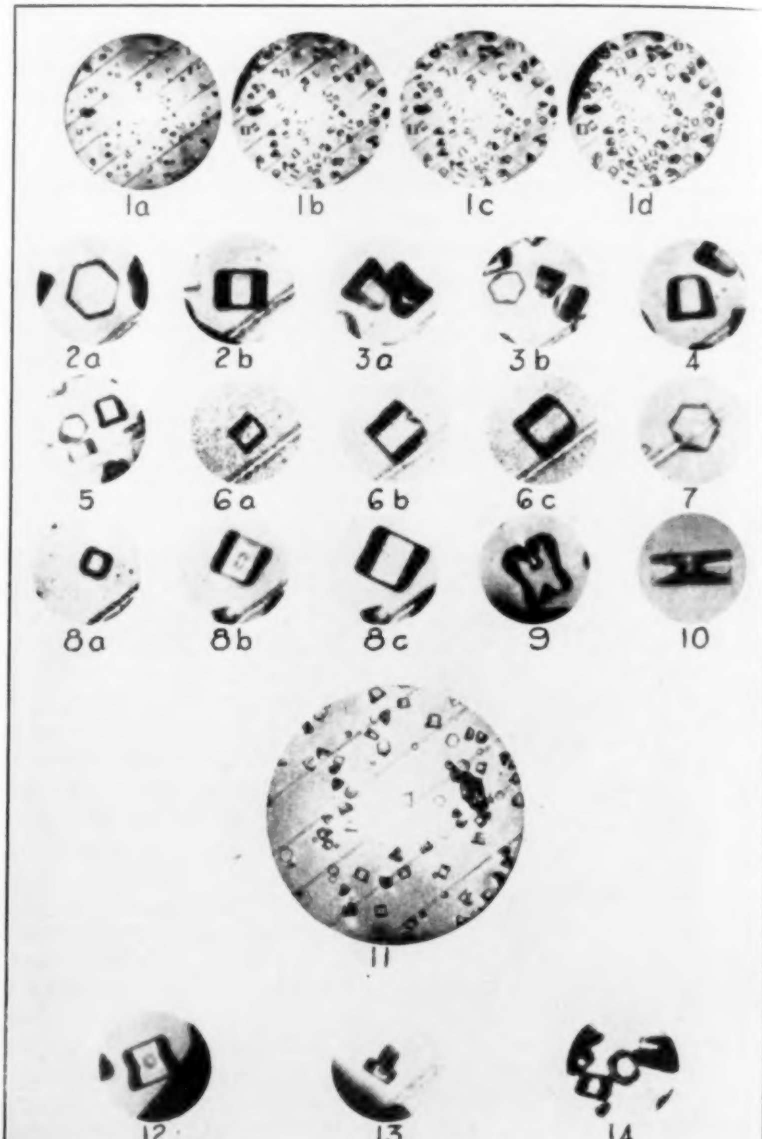
[3] Adams, *Phys. Rev.*, 35, p. 113, 1930.

cloud consists of particles of ice formed directly from the vapor. To preserve these particles for study at leisure it is necessary only to bring them at once into an observation chamber which has been precooled to the temperature at which they were formed. In the comparatively stagnant air of this chamber they settle to its floor, alighting there on a glass plate ruled with lines 0.004 inch apart. Directly under this plate, and focused on its upper surface, is a microscope-objective, cooled with the chamber and protected by insulating windows from the warmth outside. The chamber is lighted from the top, and a magnified image of the ice particles, with the rulings, is formed by the objective and is brought out through the windows, to be viewed in an eye-piece or photographed directly on a film.

The earliest indication that the ice-particles have been formed is observed before they reach the plate in a reddish opalescence of the space above it. To produce this effect the particles must be of the order of 0.00004 inch in dimensions, and they are probably not manyfold larger when they arrive at the plate, since at that time the objective used ($\frac{1}{8}$ inch) reveals their presence but nothing trustworthy as to their shape. Fortunately these particles have, in common with rain-drops, the property of growing at the expense of their neighbors, and it is only a matter of a few seconds until some of them have attained dimensions of the order of 0.0004 inch, and begin to show unmistakably characteristic shapes. From this point, the growth can be carried forward at will by regulating the supply of vapor, until the particles touch one another. Figs. 1*a* and 1*d* record several stages in the growth of a collection of particles. A study of such a series as this shows, first, that during growth through these stages there is no tendency whatever to develop the complications of natural snowflakes. Each particle retains its original shape while growing, and every stage is an enlarged replica of the preceding ones. This fact argues strongly for the monocrystalline character of the particles: each one builds up according to a single crystalline plan which it had from the beginning. A second conclusion which is readily drawn from these photographs relates to the simple shape which appears throughout the group, either clearly as in Figs. 2 or with accidental modifications as in Figs. 3. It is plain that the typical form of these elementary snowflakes is that of a short right hexagonal prism, the height nearly equal to the diameter of the base. The most frequent recognizable tendency to depart from this form is toward the form of Fig. 4, and this is accounted for, as will be explained below, by the twinning of two simple crystals on the basal plane. Indeed, such examples as those of Fig. 5 leave little room for doubt as to the occurrence of twinning. The re-entrant angle in the crystal at the upper right and the line of demarcation in the lower one are strong evidence for this view. Observations on natural snowflakes have disclosed indications of the same process.

Twinning of this sort, in which the components are in contact on a plane perpendicular to the singular axis of the crystal, is especially common with substances in which the singular axis is polar, that is, in which the two ends of the prism are physically distinguishable from each other. In many chemicals and minerals, one end of the prism is found to be more ready to disintegrate than the other, and with them this is the preferred twinning plane. Experiment shows[4] that the ice crystal has the same sort of polarity that these substances have: one end of the prism displays a well-marked tendency to develop a pit centrally along the singular axis under conditions which are favorable to evaporation, while the other end remains flat. Figs. 6 record

[4] Adams, Roy. Soc. Proc. A, 128, p. 588, 1930.



THE BEGINNING OF A SNOWFLAKE

FIGS. 1*a*, 1*d*. FOUR STAGES IN THE GROWTH OF A COLLECTION OF ARTIFICIAL SNOWFLAKES. THE RULINGS ARE 0.004 INCH APART. FIGS. 2*a*, 2*b*. THE SIMPLEST POSSIBLE SNOWFLAKE: A RIGHT HEXAGONAL PRISM OF MONOCRYSTALLINE ICE, MEASURING ABOUT 0.001 INCH IN EACH DIMENSION. FIGS. 3*a*, 3*b*. SOME ACCIDENTAL MODIFICATIONS OF THE RIGHT HEXAGONAL PRISMS, MAGNIFIED ABOUT 250 TIMES. FIGS. 4, 5. INDICATIONS THAT TWINNING PLAYS AN IMPORTANT PART IN THE GROWTH OF SNOWFLAKES. MAGNIFICATION FROM 150 TO 250 DIAMETERS. FIGS. 6*a*, 6*b*, 6*c*. EVIDENCE THAT THE ELEMENTARY ICE CRYSTAL IS POLAR. A HEXAGONAL PRISM HAS BEEN GROWN IN SUCH A WAY AS TO DISCLOSE A DIFFERENCE BETWEEN ITS TWO BASES. MAGNIFICATION 250

the appearance of such a pit during the development of a single crystal, and Fig. 7 gives the end view of a similar pit. A crystal twinned in the manner mentioned above retains the polar property of its components and can be made to develop at the twinning plane a cavity (Figs. 8) which subsequent cooling will obliterate. In addition to this type, the photographs show many instances of twinning on the other, more stable, basal plane, as revealed by the appearance of two pits, one at each end of the twinned crystal (Fig. 9). An extreme case of this sort is shown in Fig. 10. This physical dissymmetry of ice and of the other substances already referred to raise an interesting question as to the nature of thermal conduction in them—a question which for the present must remain unanswered.

Much light may be expected to be thrown on the behavior of these elementary snowflakes when the arrangement of the atoms in the ice crystal has been fully worked out. As to the relative location of the oxygen atoms, the facts are already established. Sir Wm. Bragg[5] proposed a structure for the oxygen lattice based on certain general considerations, and his conclusions have been brilliantly verified by Barnes,[6] who used the x-ray method of structural analysis. It is not often that a crystal lattice (except the simple cubics) can be described clearly in words, without the aid of a model, but the oxygen lattice in ice admits of a simple description. We think of a pavement of regular hexagonal tiles, and at each vertex of the hexagons we imagine an oxygen atom. Then we go over the pavement, lifting every alternate atom slightly above the general level, thus forming what Bragg calls a "puckered layer" of atoms. A second puckered layer, like the first, is prepared and is placed above the first, with the low atoms of the second layer directly above the high atoms of the first layer, and *vice versa*. The structure is continued by adding more puckered layers in the same manner. The separation of the layers, in comparison with the length of an edge of one of the original hexagons, is adjustable to agree with the axial ratio of the crystal as determined crystallographically or by the x-ray analysis. It will be seen that the structure so described has its singular axis vertical and makes no provision for any distinction between the two ends of this axis. Since the experimental evidence of the single crystals of ice requires this distinction, we must conclude that the hydrogen atoms are introduced into this oxygen lattice in some vertically unsymmetrical manner, in order to give the structure as a whole the necessary polarity. The exact disposition of the hydrogen is at present an open question, and in all probability will have to be settled by indirect methods, since it appears that in ice the hydrogen atom has given up its single electron to the oxygen and therefore has lost what little chance it had of being located by the x-ray analysis.

The study of the early forms of snowflakes has brought support to the theories

[5] "Concerning the Nature of Things," p. 174, 1925.

[6] Roy. Soc. Proc. A, 125, p. 670, 1929.

DIAMETERS. FIG. 7. AN END VIEW OF A PIT SIMILAR TO THE ONE SHOWN SIDEWISE IN FIG. 6. FIGS. 8*a*, 8*b*, 8*c*. WHEN TWINNING HAS OCCURRED ON THE BASE WHICH IS SUBJECT TO PITTING, THE FACT IS REVEALED BY A CAVITY. MAGNIFICATION 250 DIAMETERS. FIGS. 9, 10. THE CONVERSE OF FIG. 8*b*. A CRYSTAL TWINNED ON THE STABLE BASAL PLANE TENDS TO DISINTEGRATE BY PITTING AT BOTH ENDS. FIG. 11. SHOWING SEVERAL INSTANCES OF THE BEGINNING OF T-SHAPED FORMS. MAGNIFICATION 55 DIAMETERS. FIG. 12. THE T-SHAPED CRYSTALS SEEM TO DEVELOP FROM TWINS LIKE THOSE OF FIG. 8. FIGS. 13, 14. T-SHAPED CRYSTALS VIEWED SIDEWISE AND ENDWISE.

which the meteorologists[7] have advanced to explain the optical atmospheric phenomena seen in high latitudes, known as halos, sun-dogs, and the like. One of the commonest of these is the halo of 22°, which may be seen surrounding the sun or moon when the sky is slightly overcast by a snow-cloud. The effect has been attributed to the presence of 60° prisms of ice, of such a size as to be floating downward imperceptibly and of such a shape as to admit of a completely random orientation of the faces forming the refracting angle. The minimum deviation of light refracted by such a prism of ice is 22°, and it is in this direction that the refracted light is most intense. Evidently the crystals of Figs. 2 and 3 meet the requirements, since the proportions of these crystals are such as to permit them to fall equally readily in any position, and since light entering one of the six lateral faces, passing within the crystal parallel to the next face, and emerging on the third face, would be in effect passing through a 60° prism at minimum deviation. The same type of crystal is competent to account for the halo of 46°, which requires a refracting angle of 90°, the light entering on a basal plane and emerging on one of the lateral faces, or *vice versa*. The sun-dogs or mock suns of 22° are pale discs of light which are sometimes seen on either side of the sun and level with it. The accepted explanation is similar to that for the corresponding halo, except that all the 60° prisms must be falling with their refracting edges vertical. To account for this uniform orientation, it was assumed that the crystals were T-shaped, since it was known that the addition of a tabular cap to a prism would tend to make it fall vertically through the air, and since occasional natural snowflakes of a T-shape or an H-shape had been observed. This hypothesis is now amply supported by Fig. 11, in which the tendency of many of the crystals to develop a cap on one end of the prism is clear. Fig. 12 shows this tendency associated with the evidence for twinning already mentioned. Finally, in Fig. 13, we have a well-developed T-form, and in Fig. 14 at the center an endwise view of the same phenomenon. It may be safely concluded that in a twinned crystal one of the components tends to develop in breadth faster than the other, though for what reason we do not yet know. In this connection it would be interesting to observe whether the sun-dogs make their appearance, as a rule, subsequently to the halo. Altogether it appears that the commonest atmospheric phenomena attributed to snowflakes require for their explanation precisely those forms of crystals which occur most commonly in the laboratory snow-cloud.

The experiments here recounted trace the growth of snowflakes from 0.0002 inch to 0.002 inch diameter. They show that at that stage of development the typical snowflake is a short right hexagonal column, about as broad as it is high, consisting sometimes of a single crystal but more often of two single crystals united by twinning on the basal plane. A well marked tendency of these twinned crystals to develop into a tabular form is disclosed. It has been proved that the two basal planes of the ice crystal are physically distinguishable, and therefore that the twin crystals are of two types. So much seems well established. The questions proposed at the beginning of this article remain for further study.

[7] Humphreys, "Physics of the Air," Pt. III, Chap. IV, 1920.

THE PROGRESS OF SCIENCE

THE RESEARCH AWARD FOR THE LIVER TREATMENT OF ANEMIA

In recognition of their discovery of a therapeutic agent for the treatment of pernicious anemia, Dr. George H. Whipple and Dr. George R. Minot have been jointly awarded one of the largest prizes in America for scientific accomplishment.

Dr. Whipple, who discovered the principle of the cure, and Dr. Minot, who perfected it and applied it to human beings, each received $5,000 and a gold medal in commemoration of their work. The presentation was made by Dr. Robert A. Millikan, chairman of the executive council of the California Institute of Technology, at a gathering of scientific men and leaders in industry at the University Club in New York City.

The prize was established early last year by *The Popular Science Monthly* to increase the interest of the American people in the conquests of the laboratory and the workshop which benefit the whole community, and to focus attention upon the many scientific men and women who work to better man's control over his physical surroundings.

Dr. Whipple and Dr. Minot discovered the fact that a diet of liver will greatly relieve a sufferer of pernicious anemia. The two men, working independently of each other, found that the organs of certain animals and birds, such as the liver, kidney and heart, but especially the liver, contain a substance which stimulates the formation of red corpuscles and increases them in the circulating blood.

Anemia is caused by a diminution of red corpuscles and of hemoglobin, which is the coloring matter that makes them red. There are two forms of this disease, primary and secondary anemia. Secondary anemia accompanies some other disease, such as cancer and tuberculosis. Primary anemia is pernicious anemia. It is in itself a major disease and its essential cause is not known. Before Dr. Whipple and Dr. Minot made their discovery, a case of pernicious anemia was likely to result in the death of the patient.

Dr. Whipple's part in the discovery was the result of laboratory experiments. Dogs were used in the investigation, because these animals have the same blood picture as man. He bled the dogs gradually until the red blood cells were about one third the normal count, thus inducing severe anemia. He then began to experiment with various diets. A large number of foodstuffs were tested over a number of years, and it was found that liver was the most active factor in restoring red blood cells. Dr. Whipple, however, did not apply his discovery to human beings, nor did he appreciate the fact that the liver treatment would prove effective in pernicious or primary anemia. His dogs had secondary anemia. Primary anemia can not be induced by any known laboratory method.

It was Dr. Minot who perfected the treatment for human patients and who successfully applied it to cases of pernicious anemia. His investigations showed that pernicious anemia resulted from a deficiency in the function of the bone marrow, which forms the red blood corpuscles, and that liver was a marrow builder. In 1922 he began to experiment with various diets and four years later he was able to announce that forty-five sufferers from pernicious

THE PRESENTATION OF THE AWARD

BY DR. ROBERT A. MILLIKAN TO PROFESSOR GEORGE H. WHIPPLE AND PROFESSOR GEORGE R. MINOT FOR THEIR DISCOVERY AND DEVELOPMENT OF THE LIVER TREATMENT FOR ANEMIA.

anemia had recovered as a result of the liver diet. Since then, Dr. Minot and his associates have succeeded in separating an effective extract of liver that may be taken in powdered form. Dr. Whipple and his assistants have done the same thing, so far as the chemical extract that cures secondary anemia is concerned. Thus, it has been possible to concentrate and purify extracts that represent only three per cent. of the entire liver weight and yet contain eighty per cent. of the potency of the liver. This so-called liver fraction has been in successful use in many hospitals for more than a year.

For a number of years Dr. Whipple has been professor of pathology and dean of the School of Medicine and Dentistry at the University of Rochester. Formerly he was director of the Hooper Foundation and professor of research medicine at the University of California. Dr. Minot is professor of clinical medicine at Harvard Medical School and chief of the medical laboratories of the Huntington Memorial Hospital. The recipients of the prize were chosen by a committee of over twenty distinguished men of science, under the general chairmanship of Professor Collins P. Bliss, associate dean of New York University and director of The Popular Science Institute.

DR. ALOIS F. KOVARIK

PROFESSOR OF PHYSICS AT YALE UNIVERSITY, WHO IS A MEMBER OF THE NATIONAL RESEARCH COUNCIL COMMITTEE ON THE AGE OF THE EARTH. DR. KOVARIK IS SHOWN IN HIS LABORATORY WITH SOME OF HIS INSTRUMENTS USED IN ESTIMATING THE AGE OF THE EARTH BY RADIOACTIVE METHODS.

THE STATUE OF OERSTED IN COPENHAGEN

THE OERSTED CONSIDERED AS A NEW INTERNATIONAL MAGNETIC UNIT

There are eight electrical units, whose names by international agreement are used all over the world in electrical science and industry. Two or three of these are in such common use that their names are familiar to a large section of the general public. The two most generally known are, perhaps, the *watt* and the *volt*. The *watt*, which is the unit of power, or rate of doing work of any kind (mechanical, thermal, electrical, chemical, etc.) is named after James Watt, the Scottish scientist, inventor and engineer. James Watt revolutionized the design and construction of the steam engine, and in order to measure the power of his engines, he determined the average working rate of certain brewery horses engaged in pumping water steadily from a known depth. To a certain rate of lifting weight so derived, he gave the name *horse power*. It probably never occurred to him that his own name would be subsequently applied to an international unit of power.

In a similar manner, the *volt*, which is the unit of electric tension or electromotive force, is named after the Italian physicist Alessandro Volta, the discoverer and first inventor of the voltaic cell.

The complete series of international electrical units, as adopted up to date, is given in the accompanying table. Numbers 9 and 10 in the table are magnetic units adopted at the International Electrical Congress of Paris in 1900. As is indicated in column III, there was a certain ambiguity about the nature of the *gauss* at the time of its adoption. The proposers of the *gauss* intended it to be the unit of magnetic flux density B; but, by a misunderstanding, it appeared to have been adopted as the unit of magnetizing force H. There was subsequently a considerable amount of con-

TABLE OF ELECTRIC AND MAGNETIC UNITS

Number	Unit name	Symbol	For electric	Named after	Lived	Country	Adopted Year	Adopted At
1	Volt	E	Tension	A. Volta	1745–1827	Italy	1881	Paris
2	Ohm	R	Resistance	G. S. Ohm	1778–1854	Germany	1881	Paris
3	Ampere	I	Current	A. M. Ampère	1775–1836	France	1881	Paris
4	Coulomb	Q	Quantity	C. A. Coulomb	1736–1806	France	1881	Paris
5	Farad	C	Capacitance	M. Faraday	1791–1867	England	1881	Paris
6	Joule	W	Work	J. P. Joule	1818–1889	England	1889	Paris
7	Watt	P	Power	J. Watt	1736–1819	Scotland	1889	Paris
8	Henry	L	Inductance	J. Henry	1799–1878	America	1893	Chicago
			For magnetic					
9	Maxwell	Φ	Flux	J. C. Maxwell	1831–1879	England	1900	Paris
10	Gauss	H / B	Force / Flux density	K. F. Gauss	1777–1855	Germany	1900	Paris
11	Gilbert	F	Magnetomotive force	W. Gilbert	1540–1603	England	1930	Oslo
12	Oersted	H	Force	H. C. Oersted	1777–1851	Denmark	1930	Oslo

fusion in technical literature, some writers using the gauss for the unit of H, others for the unit of B, and still others for both. The matter was further complicated by the fact that the quantity H has been used in two different senses; namely, (1) the magnetizing force due to the exciting current-turns linked with a magnetic circuit, and (2) the intensity of the magnetic field produced by the exciting current when the magnetic circuit is a vacuum or contains no magnetic material. Differences of opinion and of usage became so numerous and wide-spread that the matter was referred to the meeting of the International Electrotechnical Commission (I. E. C.) in Scandinavia last summer (June–July, 1930). At that meeting, the I. E. C. decided that, for electrotechnical purposes, magnetizing force H should be regarded as essentially different from field intensity B_0 or flux density B. To the latter the unit name of *gauss* should be restricted; while the name *oersted* was adopted for the unit of magnetizing force H, by way of distinction.

Hans Christian Oersted (in Latin, Johannis Christianus Örsted was, in 1820, professor of physics in the University of Copenhagen, Denmark. In the spring of that year, he made laboratory experiments in search of some connection between magnetism and electricity. Up to that date, those two sciences were regarded as unconnected and independent. The science of electricity was well recognized, and also the science of magnetism—essentially pertaining to permanent magnets; but there was no such science as electromagnetism. He discovered that when a wire, carrying a steady electric current, was brought into the neighborhood of a horizontally suspended magnetic needle, such as the needle of a mariner's compass, the needle was deflected from its normal north-south position, and remained so deflected as long as the current flowed in the wire, or as long as the active wire remained in the needle's vicinity. This remarkable experiment, repeated in a number of different ways, was described by Oersted in a circular letter, printed in Latin, at that time an international language in considerable vogue, and addressed to a number of universities and learned societies throughout the world, bearing the date of July 21, 1820.

Ever since 1820, electricity and magnetism have been regarded as indissolubly connected. The union led shortly afterwards, through the work of other scientists, to further discoveries in electromagnetism which have profoundly affected the conduct of civilized life.

The accompanying illustration is from a photograph of a statue of Oersted, which has been erected to the memory of this distinguished Danish discoverer in a park at Copenhagen, known as the Oersted Park. It represents the discoverer standing beside a pedestal bearing a freely supported magnetic needle which he is showing to be deflected by the influence of a current-carrying loop of wire leading to a voltaic battery at his feet. The front inscription reads "Hans Christian Oersted" and the inscription at the back, as translated from the Danish, reads "Born 14th August, 1777, Died 9th March, 1851." On the occasion of its visit to Copenhagen, June 27, 1930, the visiting I. E. C. officers and delegates formally placed a suitably inscribed commemoration wreath in front of this statue.

ARTHUR E. KENNELLY

ELLWOOD HENDRICK

LATE CURATOR OF THE CHANDLER CHEMICAL MUSEUM OF COLUMBIA UNIVERSITY, WHO DIED IN HIS SIXTY-NINTH YEAR. THE PORTRAIT IS THE WORK OF AUGUSTUS VINCENT TACK.

THE LAST HEATH HEN

On Martha's Vineyard Island off the southeastern coast of Massachusetts is the home of the lone survivor of the heath hen. The death of this individual will also mean the death of its race, and then another bird will have taken its place among the endless array of extinct forms. The numbers of heath hen have been closely followed by ornithologists and since 1908 a detailed census has been taken of the birds each year. For the first time in the history of ornithology a species has been studied and photographed in its normal environment down to the very last individual.

In early colonial times the heath hen was very abundant in favorable places from Maine to the Carolinas. The bird's habit of congregating in open fields and the ease with which it was tricked and killed by the market gunners were contributing factors to its rapid decline soon after the white man and his firearms came to America. By 1870 the heath hen was exterminated from the mainland and from that time on has been restricted to its last stronghold on Martha's Vineyard. It is remarkable that a bird subjected to all the vicissitudes of disease and enemies has survived in that limited area for over a half century. The prolongation of the life of the bird on that island has been due to the interest taken in it by the State of Massachusetts, conservation organizations, bird clubs and individuals who have done all in their power to save the bird. The State Department of Conservation has expended $70,000 and thousands more have been contributed by individuals in the unprecedented efforts to prevent the bird from being exterminated.

Many attempts were made in the past when the birds were abundant to transplant them to other favorable places on the mainland and to other islands such as Long Island, New York, one of their former strongholds. Furthermore the most experienced sportsmen and game breeders were unable to breed the birds in captivity, indicating that the heath hen was very sensitive to any radical change in its environment and that it would not yield to such methods of conservation. All the many experiments of introducing the Western Prairie Chicken, its nearest relative, to the East have likewise proved unsuccessful. Efforts to increase the numbers of the heath hen on Martha's Vineyard by the establishment of a reservation in 1908 met with temporary success. The birds increased from less than 100 to an estimated number of 2,000 in 1916. Unfortunately a destructive fire swept over the entire breeding area on May 12, 1916, which in the course of a few hours undid the work of many years. The following year there were less than 150 birds remaining, and the majority of these were males. There was a slight rally in numbers during the following few years, but the birds were too far gone to overcome the surmounting uncontrollable conditions of extensive interbreeding, declining sexual vigor, the condition of excess males and, worst of all, disease. In 1920 many birds were found dead, or in a weak and helpless condition, indicating that disease was exacting its toll. The heath hen is very susceptible to poultry diseases and when domestic turkeys were introduced to the island in large numbers the dreaded disease "Blackhead" came with them. The turkeys and heath hen fed on the same fields and thus the disease was readily transmitted to the native birds. The heath hen continued to decrease in numbers, and by 1925 it was apparent that they had reached their lowest ebb in history. The Federation of the Bird Clubs of New England, Inc., then came to the front and offered to raise $2,000 annually to support additional warden

THE LAST HEATH HEN

service. In spite of this splendid co-operation, the number of birds, after two years of effort on the part of all concerned, continued to decrease.

The 1927 spring census showed thirteen birds, only two of which were females. In the autumn seven birds were seen and by April, 1928, the flock dwindled to three males. During the fall of 1928 only two birds were seen and after December 8 but one was reported. This bird was photographed from a blind, on April 2, 1929, at the farm of James Green, located on the state highway between Edgartown and West Tisbury. At that time it was the common expectation that the bird would step out of existence before the end of another year. It was seen regularly until May 11, 1929, but after that date it disappeared among the scrub oaks to live in seclusion, as was customary for the heath hen to do in the past, during the summer months. After the moulting season it again appeared at the Green farm in October to announce to the world that it was still alive. It was seen at irregular intervals during the winter, and after the first warm days of March it appeared daily at the traditional "booming field" at the Green farm. The State Department again placed an observation blind in the field and baited the bird for over a month in order to make it possible to study and to photograph it at close range during the period of the census.

During the springtime of former years the heath hen appeared in the open fields in the early morning hours following dawn and again in the late afternoon preceding sunset, to go through their weird and extraordinary courtship performances. This year the

lone bird generally flew out of the scrub oaks and sailed gracefully to a point near the center of the meadow. After alighting it erected its head and carefully scrutinized its surroundings, seeming to make sure that all was safe before continuing to search for food. The bird presented a pathetic figure as it stood out there all alone without any companions save the crows that had come to share the food intended for the heath hen. Though it soon started feeding it was ever on the alert for possible danger. Its eyes were much keener than those of the observer inside the blind. On several occasions the bird crouched in the grass, his colors blending so perfectly with the surroundings that he disappeared from view. A minute or two later a hawk would swoop over the field, explaining the reason for this behavior. No doubt the alertness of this individual has been an important factor in its preservation. The feeding in the open was a businesslike performance and during the time of the census was not interrupted by the booming and cackling characteristic of the courtship performance, which in former years occupied the greater part of the time of the males during the visits to the open fields. Not once did the male inflate his curious orange sacs and boom, for there was no female to admire him and no male to challenge him to such an exertion. Its spirit must be broken, but nevertheless it seems to enjoy its life and its freedom. It is in excellent health, fat and plump and in perfect plumage.

The State Department has been asked to collect and preserve this last bird for science, but from a sentimental point of view how much better it is to let this individual live in its natural environment among the scrub oaks on the sandy plains of Martha's Vineyard than it would be to put it in a cage or to mount it and have it collect dust on some museum shelf.

How long the bird will live no one can safely predict; its going is inevitable, but ornithologists, bird lovers and sportsmen the world over will have the satisfaction of knowing that all that could be done by the state, bird clubs and individuals has been done to save it from extinction. The State Department has assured us that the bird will be allowed to live, and when death comes, whether it is due to old age, disease or violence, we shall at least know that the life of the last heath hen was not wilfully snuffed out by man.—A. O. G.